Journal and Proceedings

of the

Royal Society
of
New South Wales

2022

Volume 155 Part 2

Numbers 487 & 488

"... for the encouragement of studies and investigations in Science Art Literature and Philosophy ..."

The Royal Society of New South Wales

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The Society traces its origin to the *Philosophical Society of Australasia* founded in Sydney in 1821. The Society exists for "*the encouragement of studies and investigations in Science Art Literature and Philosophy*": publishing results of scientific investigations in its *Journal and Proceedings*; conducting monthly meetings; awarding prizes and medals; and by liaising with other learned societies within Australia and internationally. Membership is open to any person whose application is acceptable to the Society. Subscriptions for the Journal are also accepted. The Society welcomes, from members and non-members, manuscripts of research and review articles in all branches of science, art, literature and philosophy for publication in the *Journal and Proceedings*.

ISSN (printed) 0035-9173
ISSN (online) 2653-1305

Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, pp. 125–130. ISSN 0035-9173/22/020125-06

Solar power, fusion, and snapping shrimp

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It is now 200 years since Governor Thomas Brisbane first convened a meeting of the Philosophical Society of Australasia in Sydney. After a COVID-related delay, the Society marked its birthday with an exhibition — NEXUS — about the history and achievements of the Society, at the State Library. Three events followed: a Garden Party hosted by the Governor at Government House on 12 March 2022; a Gala Dinner in the Great Hall of the University of Sydney, addressed by the Governor General, former patron, the former Chief Scientist of Australia, Alan Finkel, on 24 June; and a Reception at Admiralty House hosted by the Governor General on 7 November. Their addresses are printed below, as well as greetings from people and organisations around the world, a description of the NEXUS exhibition, and the programme for the Dinner.

In October, Martin Green won the Millennium Technology Prize, Finland's top technology award and often a precursor for a Nobel Prize. Professor Green was awarded the prize, worth €1 million ($1.54 million), for his work in developing the Passivated Emitter and Rear Cell (PERC), a solar cell that's proved to be so efficient, cheap and scalable that it's already changed the world by its mass deployment. His laboratory at UNSW continues to lead the world in further improvements to the cell. Many of his former PhD students now hold key leadership positions at five of the world's six major solar cell producers. I asked Professor Green, a former FRSN, whether we could publish his acceptance speech from the ceremony in Helsinki, and he agreed. Read the history of the PERC cell's development.

As the winner of the Society's 2021 History and Philosophy of Science Medal, Dean Rickles submitted a paper, "*Quis custodiet ipsos custodes*?[1] From quantum gravity to second-order cybernetics," which discusses the role of subjectivity in understanding reality in fundamental physics. The paper is accompanied by a famous sketch by Max Escher of two hands drawing each other, which, Rickles believes, captures the role of the observer in quantum gravity, and consciousness. See what you think.

There follow two papers on science-related government policy. Peter Shergold FRSN has written a summary of the findings of a committee he chaired on Australian governments' responses to the COVID pandemic. With no government funding, and no government representatives, this report is truly independent. One important recommendation is that Australia establish a national Centre for Disease Control. Apparently we are the only OECD nation to lack such a centralised organisation, and readers might remember an earlier call for such a body in Eddie Holmes' paper (2019). Shergold's summary ends with the admo-

1 My understanding of this is: Who will guard the guardians themselves (*ipsos*)? [Ed.]

nition that we must learn from our recent experience so that we are better able to deal with the next pandemic, "which will come."

As a consequence of the AUKUS agreement among Australia, the UK, and the USA, for Australian nuclear-powered submarines, Brian Schmidt DistFRSN reflects on Australia's growing need for STEM graduates to service the machines. He argues that we should view the subsequent demand for qualified graduates as an opportunity to alter our universities' approach to STEM-focussed students, as Australia builds a support industry from scratch for submarine maintenance.

Andrew Blakers FRSN and colleagues have recently published an Atlas of Bluefield Sites for pumped hydro energy storage (PHES). PHES is a means of augmenting renewable energy by storing it as the potential energy in water pumped from a lower to a higher reservoir, for release to the lower dam via electricity-generating turbines. Only one new reservoir is required per Bluefield site. For the Bluefield Atlas, Blakers and his associates searched near every existing reservoir in Australia to find a potential matching reservoir site to form a PHES pair. This follows Blakers (2020), a contribution the Point Counterpoint debate about energy. PHES facilities are needed to make firmed renewable energy available when solar and wind power are not sufficient. Unlike Snowy 2.0, the small-scale sites identified in the Atlas could be built with low costs and much lower environmental impacts.

A final paper is a departure. Some Australian readers might remember a book first published in 1952, *Australian Seashores*, by Dakin, Bennett, and Pope, reprinted and revised until 1987. Seventy years ago it was noteworthy in having two female authors, Isobel Bennett of the University of Sydney and Elizabeth Carrington Pope of the Australian Museum. An exhibition at the University of Sydney's Chau Chak Wing Museum (2022–2023) celebrates the landmark volume. The exhibition's curators, Anthony Gill and Kelsey McMorrow, at my request, have written a paper describing the book, the exhibition, the three authors, and the collection. The book mentions the mystery of the snapping shrimp, *Alphaeus strenuous*, which has evolved a way to, presumably, scare off predators with a deafening "snap!" How does it produce this sound? We now know that it occurs through cavitating bubbles. The book pioneered the idea of "citizen science" in Australia.

Since 2016, we have published 107 abstracts from dissertations of PhD graduates from NSW and the A.C.T. An abstract this issue caught my eye: Dr Lara Cullinane, who graduated from ANU and is now at Johns Hopkins in the U.S.A., studied the structure and movements of the interactions between the Large and Small Magellanic Clouds which are clearly visible in the southern sky. But not, ironically, from Maryland.

Wildlife in the suburbs

The Australian Brush Turkey (*Alectura lathami*) is commonly found north of Sydney, where they have established themselves in suburban gardens, as well as the brush (i.e. rainforest), where their common name suggests they are more at home.[2] Recently, however, they have crossed the Harbour. Last year I saw my first Brush Turkey in

2 Also known as the Scrub Turkey, where "scrub" is another settler word for rainforest.

Balmain. They built a mound or nest in the Terman Street Reserve, where at least four chicks hatched and survived. Later, I learnt that another mound was built in the gardens of Ewenton House. This year, the Terman Street Reserve mound has been renewed, and a new mound also built on land at the end of Blake Street, where one chick or poult (sadly since dead) has hatched.

How did the Brush Turkeys cross the Harbour? They can fly, at least enough to flee cats and to chase each other through the trees of the Reserve, so did they fly across? Walking is unlikely, although there is one report of a Brush Turkey on the Harbour Bridge. Will they continue south? It would be a bold prediction to say that they will never be found in Sydney's western suburbs. The rainforest of the Illawarra awaits.[3]

Fusion power?

Recent breathless reports tell of successful fusion at the National Ignition Facility in California. They tell of a net energy output with a fusion reaction of deuterium and tritium, two isotopes of hydrogen. Compressed together sufficiently tightly by laser, their nuclei fuse to create a helium nucleus, a neutron and some energy. The compression must overcome the mutual repulsion of the positively charged nuclei and push them sufficiently close for the short-range strong nuclear force to take over. This force attracts the nuclei together into the new helium nucleus, which needs less energy to bind it than do the parents. The surplus energy is released. Such an outcome — Net Energy Gain — had never been achieved before. But the net positive energy is solely accounting for the energy focussed on the two isotopes, not the very much larger amounts of energy needed to prep the aging lasers. And the amount of energy produced by the fusion was small, and was only for a few nano seconds. To scale this process up will require tremendous engineering developments. Yes, fusion is carbon-free, but so too is fission. And wind and solar renewables are not only radiation- and carbon-free, but they are technically and economically feasible now. Nonetheless, noted theoretical physicist Heinrich Hora FRSN is associated with an Australian start-up, HB11 Energy, that is focussed on fusion (Lu 2022).

The first functioning laser (Light Amplification by Stimulated Emission of Radiation) was constructed in 1960. For the next twenty years, Heinrich Hora researched the applications of lasers for producing nuclear fusion energy. Hydrogen–boron 11 fusion has always been the ultimate fusion reaction. It does not create radioactive waste (no neutrons produced,[4] only three helium nuclei and kinetic energy) and its fuels, hydrogen H — not deuterium or tritium — and boron 11, are both abundant in nature (unlike deuterium and tritium) and non-radioactive. Few other researchers had studied this reaction, as it was considered too difficult to achieve. The temperatures required to ignite the reaction are more than 100 times higher than that of the sun — a technical hurdle that has held back practical energy generation for decades.[5]

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3 A recent book is (Hunter 2018). See also Bolger & McCullagh (2022).

4 No neutrons are produced when the reacting H-nuclei (protons) have energy lower than about 3 MeV (Hora et al. 2017).

5 I have borrowed from the HB11 Energy web site for this description, https://hb11.energy/our-story/

In 1978, Professor Hora explored an alternate means of achieving the fusion reaction without high temperatures. But his approach suggested using lasers that did not yet exist. This changed dramatically after Donna Strickland and Gerard Mourou demonstrated Chirped Pulse Amplification (CPA) of lasers in 1985. Their experiment set a direction for high-power laser technology development. In recent years, scientists have reached the requirements first predicted by Prof. Hora to achieve the HB11 reaction.[6] Their work on CPA lasers won Strickland and Mourou the 2018 Nobel Prize in Physics.

The HB11 fusion process is radically different from the previous focus of generating fusion via thermal equilibrium — i.e. heating the fuels to tens of millions of degrees C to achieve ignition. In contrast, by using CPA lasers or their successors, the HB11 concept offers an alternative that does not require heating fuels to extreme temperatures. As their concept converts nuclear power directly into electricity, HB11 Energy will not need the steam turbines and generators required for coal or conventional nuclear-fission power plants, so their plants can be much smaller and there is no risk of reactor meltdown.[7] HB11 Energy plans to use hydrogen and boron 11 nuclei as the fuel in its process, as this fusion reaction produces much less radiation than the deuterium-tritium reaction. Read Hora et al. (2017) and Daponta et al. (2022) for the details. But don't hold your breath: this too is far from ready.

DOIs and the Royal Society

Readers who have used the Contents (or Archive) web page of the *Journal & Proceedings* will perhaps be aware that the Biodiversity Heritage Library (BHL), a branch of the Smithsonian Institution in Washington D.C., have scanned back issues of the *J&P* since 1867 and earlier, and have placed these scans on-line in their repository, to which a click will direct the researcher from our Contents page. We had lost contact with the BHL until, as a result of Councillor Davina Jackson's efforts to build a single index of author and title for all papers since 1821, I re-established contact with the BHL (our last direct contact had been in 2014). We found that the BHL has undertaken to provide DOIs (Digital Object Identifiers) for all papers in their repository, including all 2,000-odd of the Society's published papers back to 1867 and earlier. We quickly signed up.

For a year or so we had been considering obtaining DOIs for our recent papers, but had been daunted by the logistics and cost. We therefore jumped at their offer. Some years ago we had obtained an ISSN for the on-line version of the *Journal*, a requirement for allocation of DOIs. After I took over as editor in 2016, I spent six weeks indexing the BHL repository of Royal Society papers — author, title, journal, pagination, issue and volume, dates and, significantly, each paper's URL in the BHL repository. These are the metadata associated with each paper, absolutely necessary for the DOIs. And for the Contents Archive pages on the Society's web site.

6 The petawatt laser used was in Japan; Australia does not have such a facility. https://www.afr.com/technology/bold-plan-to-generate-limitless-power-with-giant-lasers-20220216-p59x29

7 See Subramanian (2022) for a description of the problems and costs of decommissioning a nuclear fission reactor, with its attendant radioactivity.

They have begun. The BHL has already provided us with the DOIs for the Society's earliest publications, the *Transactions of the Philosophical Society of New South Wales, 1862–1865*, and the *Transactions of the Royal Society of New South Wales*, 1867–1874. They are continuing with the *Journal & Proceedings* 1875–. (Although the Contents/Archive pages point to presentations made at earlier Society meetings, these were not published, if at all, in Society publications, are not available from the BHL repository, and so will not be allocated DOIs by the BHL; the content is still available online, usually at the National Library of Australia's Trove database.) These earliest DOIs have been added to the Contents/Archive pages, as will the DOIs to later papers. The DOI points to the metadata for each paper, and from there is a link to the paper on the BHL repository.

What is so special about DOIs, I hear you ask? The DOI system provides a technical and social infrastructure for the registration and use of unique persistent identifiers, DOIs, for use on digital systems. The unique string of numbers, letters, and symbols is used to identify an article or document (journal articles, research reports, data sets, and official publications). Each DOI is resolved to its target, the object to which the DOI refers, achieved by binding each DOI to metadata about the object, including its URL, where the object is located on the web. Thus, by being actionable (and interoperable) a DOI differs from an ISBN or ISSN, which is an identifier only. Each DOI remains fixed over the lifetime of its document, whereas the metadata may change. If so, the publisher must update the metadata associated with the DOI, such as its URL.

DOIs were introduced in 2000, coincidentally the year in which the Society started systematically making the pages of the *Journal* freely available online. Since then, approximately 275 million unique DOIs have been assigned. With DOIs for all the papers in our publications, the Society and its *Journal & Proceedings* fully joins the world of digital publications.

Recently we have received news of the deaths of two Fellows: Ragbir Bhathal FRSN, a past president and librarian of the Society, died on 30 November 2022, aged 86.[8] Chris Fell AO FRSN died on 8 December 2022, aged 82. We shall print obituaries of the two men in 2023.

Housekeeping

Donald Hector, past president of the Society, past editor of the *Journal*, and stalwart member of the *Journal*'s editorial board, has stepped up to help me with my editorial duties. He recently suggested that we put out a call for longer, reflective, essay-style papers that we could consider publishing in a separate issue. A good suggestion, and we hereby invite such submissions.

As usual I thank Jason Antony MRSN for his excellent text processing, and Rory McGuire MRSN and Michael Burton for their proof-reading; Len Fisher FRSN gave me valuable advice on physics. As an aside, I ran an earlier version of this editorial through the new AI wonder, ChatGPT;[9] it suggested readability changes, some of which I have adopted here. My judgement? It's nothing spectacular as a copy editor.

8 As one of a series of interviews he conducted with prominent Australian scientists, Professor Bhathal organised an interview with Ron Bracewell AO that was published in the *Journal* as Bracewell and Bhathal (2018).

9 See https://openai.com/blog/chatgpt/

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Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, pp. 131–133. ISSN 0035-9173/22/020131-03

Bicentennial celebrations
The Bicentennial Garden Party

Her Excellency, the Honourable Margaret Beazley AC QC

The speech given by Her Excellency, The Honourable Margaret Beazley AC QC, Governor of New South Wales, on 12 March 2022 at Government House on the occasion of The Royal Society of New South Wales's Bicentenary Garden Party.[1]

Bujari gamarruwa
Diyn Babana Gamarada Gadigal Ngura

In the Sydney language of the people of the Eora Nation, I welcome you to Government House. In paying my respects to Elders, past, present and emerging of the Gadigal and of the Indigenous nations across New South Wales, I recognise their deep knowledge, care and custodianship of land, seas and waterways.

I welcome Dr Susan Pond AM, President of the RSNSW, the Royal Society Fellows and Members — what I would term the Royal Society Family! I especially welcome descendants and family members of former Presidents, including of James Douglas Stewart, the Society's President in 1927, a renowned veterinary scientist, and of David Branigan AM, the Royal Society's President in 1995, and an eminent geologist. In recognising the service of Presidents, past and present, I acknowledge that of John Hardie AM, the longest serving President, whose membership of the Royal Society spans a quarter of the history of the Royal Society in NSW.

The Royal Society of New South Wales and its progenitor societies have deeply impacted the intellectual life of our nation. Much of that has been recorded in its unique library collection, charting the evolution of intellectual thought in New South Wales for 200 years.

Had there been an opening celebratory garden party all those 200 years ago, it would have been across the road in Bridge Street on the site of Old Government House, construction of this House not commencing until the late 1830s, with the Governor taking up residence in 1846. The Moreton Bay Fig tree which stands so grandly beside the House was planted as a sapling at that time.

As at the Society's founding date, there were few local Indigenous people, the population having been decimated by a smallpox outbreak which left the community bereft of its elders and thus its leadership. Its impact remains today. The European population numbered some 30,000. Although the number of free settlers had begun to increase rapidly after the end of the Napoleonic Wars, convicts still comprised 40% of the white population. Squatters had begun to occupy the vast plains of rural New South Wales following the first inland settlement in Bathurst.

The New South Wales Legislative Council, an appointed legislative body providing advice to the Governor and Australia's

1 Reprinted from the RSNSW *Bulletin* 461, April 2022. Edited by Jason Antony and Bruce Ramage. https://royalsoc.org.au/submit-bulletin-documents/2022-issues/386-461-april/file

oldest legislative body, was not established until 1823.[2]

It was into this disparate admixture of peoples that the Philosophical Society of Australasia stepped in 1821, with ten members, and Governor Brisbane as first President, established "with a view to enquiring into the various branches of physical science of this vast continent and its adjacent regions."[3] Society members met at each other's homes, sharing the books and papers they had brought with them, or were able to have shipped from London, encouraging one another in their scientific interests.

Professor A.J. Elkin in his 1966 Centenary[4] Oration described the aspirations of those first members thus: "These little gatherings held out hopes of being oases of refreshment in what must have seemed a cultural desert."[5] That refreshing start — as visionary as it was — would be short-lived.

By the end of 1822, Judge Barron Field had written that the "little Society" has "expired in the baneful atmosphere of distracted politics."[6] He revised that description a few years later, stating that the Society was "in a state of suspended animation."[7] Three decades later the establishment of Sydney University, which had been the great dream of the Society, gave it a significant new lease of life.[8]

The path since has not always been smooth, with vicissitudes of impecuniousness, politics, fallings-out and fallings back-in, and with the significant honour of Royal favour being conferred in 1866. But through it all, the Royal Society has continued to be that nexus of ideas and discovery, challenging us to think differently, analyse the latest research, to discuss, debate and understand some of the major issues confronting humanity.

So it is, that in marking 200 years, we have much to celebrate:

- 3260 papers delivered to the Society in all its forms, since 1822, most published in scholarly journals;
- The oldest and most prestigious awards in Australia;
- 480 Fellows, including 17 Distinguished Fellows — at 2021 count! — and 212 esteemed Members;
- Seven annual Royal Society and Four Learned Academies Forums, hosted here at Government House;
- The success of *Ideas@theHouse*;
- The foundation in 2021 of a new Royal Society Western branch; and
- This year's fascinating *NEXUS* exhibition, held at the State Library.[9]

2 https://www.parliament.nsw.gov.au/lc/roleandhistory/Pages/The-history-of-the-Council.aspx

3 https://www.royalsoc.org.au/about-us/history

4 Centenary of designation as a Royal Society

5 AP Elkin: Centenary Oration (1966): page 13. https://royalsoc.org.au/images/pdf/CentenaryVolume/CV-00-Elkin.pdf

6 ibid, page 14

7 ibid, page 15

8 University of Sydney, founded 1850

9 https://www.royalsoc.org.au/events-news/events-2022

A bicentenary of an institution whose purpose has been to "enrich lives through knowledge"[10] is an occasion that richly deserves to be celebrated. Indeed, it is of State — and of national — importance that this occasion be recognised. As much as in the past, research, inquiry, discussion and debate are critical to our future.

Congratulations, Royal Society! Please join me in a Toast …

To the Royal Society of New South Wales and the next 200 years: Omnia Quaerite![11]

10 200-year motto

11 "Question everything:" Royal Society motto

Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, pp. 134–137. ISSN 0035-9173/22/020134-04

The Gala Dinner, 24 June 2022

Programme

Thank you for joining us on this historic occasion
as we recall and pay tribute to the Society's past achievements.

We invite new friends here tonight, to join our members
on our journey as we soar into our third century …

The Society acknowledges the Traditional Owners
of the land on which we meet today,
the Gadigal people of the Eora Nation
and pays respect to Elders, past, present, and emerging
and their connections to Country, knowledge, and community.

THE ROYAL SOCIETY OF NEW SOUTH WALES

A little over 200 years ago the good citizens of Sydney welcomed to the colony the sixth Governor of New South Wales, Sir Thomas Brisbane, who immediately accepted an invitation to become the President of The Philosophical Society of Australasia, the first learned society in the colony. It had been established on 27 June 1821 by a group of like-minded individuals who wanted to share intellectual pursuits a long way from cosmopolitan London and Edinburgh.

Through a series of iterations the Society became more influential and required greater certainty around its governance. In 1881 the Society was incorporated by an Act of the New South Wales Parliament which remains in force today.

The Society became a significant meeting place and home for some of the greatest thinkers and contributors to knowledge in Australia. The aviation pioneer Lawrence Hargrave, for example, published all his papers on heavier-than-air flight in the Society's *Journal & Proceedings* which has been published continuously since 1866.

The Society has broadened its scope in the 21st century, focusing on intellectual inquiry and the promotion of public interdisciplinary discussion across all areas of discovery and knowledge. The Society's Branches, first established in 1961, have expanded to enable it to better serve the whole of the State.

LAWRENCE HARGRAVE WORKING ON A BOX KITE AT POINT PIPER, SYDNEY, ABOUT 1910
COURTESY NATIONAL MUSEUM OF AUSTRALIA

(OPPOSITE) MONTAGE FROM THE ORIGINAL GLASS PLATE PHOTOGRAPH FROM HARGRAVE, LAWRENCE. AERONAUTICS, *JOURNAL & PROCEEDINGS OF THE ROYAL SOCIETY OF N.S.W.,* 32, 1898, 55–65

ORDER OF PROCEEDINGS

WELCOME TO COUNTRY
Aunty Ann Weldon

OPENING REMARKS
Dr Susan Pond AM FRSN
President

ENTRÉE

PATRON'S ADDRESS
Her Excellency the Honourable Margaret Beazley AC QC
Governor of New South Wales

SECOND COURSE

AFTER DINNER ADDRESS
All aboard – choose your flight to the future
Dr Alan Finkel AC

GOVERNOR-GENERAL'S ADDRESS
His Excellency General the Honourable David Hurley AC DSC (Retd)

TRUMPET FANFARE

CEREMONIAL CUTTING OF THE BIRTHDAY CAKE

TOAST TO THE SOCIETY

DESSERT

Carillon and Organ
Amy Johansen

Trumpet
David Foster

The Gala Dinner, 24 June 2022

MENU

Tomato tarte tatin, caramelised onion

Zucchini salfrino tart, lemon labneh, red pepper pearls

Citrus cured ocean trout, watercress, cucumber,
red radish, crème fraîche, salmon pearls

Philip Shaw The Gardener Pinot Gris 2021 Orange NSW
KT Watervale Riesling 5452 2021 Clare Valley SA

Grain fed chicken ballotine, corn velouté, pomme fondant, thyme jus

or

Dry aged fillet of beef, Paris mash, truffle mushroom ragoût

Santa Duc Vin de Pays de Vaucluse 'Les Plans' 2017 Côtes du Rhône France
Glenguin Schoolhouse Shiraz 2018 Hunter Valley NSW

Croquembouche with berries

Veuve d'Argent Cuvée Prestige Blanc de Blancs Brut France

Tea and Coffee

CELEBRATING 200 YEARS

1821–2021

1821	The Philosophical Society of Australasia was founded by six prominent citizens
1850	Revived as The Australian Philosophical Society by some of the original founders
1855	Renamed the Philosophical Society of New South Wales
1859	The first of the Society's annual *Conversazione* was held highlighting photography
1862	The Philosophical Society's *Transactions* commenced publication
1866	Queen Victoria assented to the name: The Royal Society of New South Wales
1875	The Society occupied its first permanent premises at 5 Elizabeth Street Sydney
1876	Discipline-specific 'Sections' and the Society's *Journal & Proceedings* commenced
1880	Professor The Hon John Smith MLC was elected the first non-Vice-Regal President
1881	The Society was incorporated by an Act of the New South Wales Parliament
1900	The first of the Society's Popular Science lectures was held, open to the public
1921	The Society celebrated its centenary with a series of special events
1931	Science House, with the motto 'vigour of mind prevails', was opened
1935	The first female members were elected to the Society
1953	Dr Ida Browne was elected the Society's first female President
1961	The first branch of the Society was established in the New England region
1971	The first annual science Summer School was held for senior high school students
1994	The Southern Highlands Branch of the Society was established
2011	The Society began its Annual Forums focusing on issues of community interest
2019	The Society's Hunter Branch was established
2020	The RoyalSocNSW YouTube channel was launched
2021	The Western New South Wales Branch of the Society was established

ENRICHING LIVES

THROUGH KNOWLEDGE AND INQUIRY

ENGAGE WITH US

ACKNOWLEDGEMENTS

ANNIVERSARY DISPLAY

The Society thanks the Chau Chak Wing Museum team for curating the 200th anniversary display of Society-related objects from the Macleay Collections, echoing Society *Conversazione* of the 19th and early 20th centuries when scientific discoveries were exhibited to the public.

TRUMPET FANFARE

Fanfare for the Royal Society of New South Wales on its 200th Anniversary
composed by Dr David Hush FRSN

The Society acknowledges the generous support of the following individuals and organisations that have made The Gala Dinner possible

ANDREW & PAULA LIVERIS

THE UNIVERSITY OF SYDNEY

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

Charles Sturt University

une University of New England

UTS UNIVERSITY OF TECHNOLOGY SYDNEY

UNIVERSITY OF WOLLONGONG AUSTRALIA

UNSW SYDNEY

WESTERN SYDNEY UNIVERSITY

UNIVERSITY OF CANBERRA

JOINING THE 200 CLUB

From one bi-centenarian to another, congratulations on reaching this tremendous milestone. It is an exclusive club, not only those of us who have reached 200 years but also have had a positive impact shaping the State of New South Wales. Whilst we have maintained a staunch dedication to safeguarding the agriculture of the state, you have done an outstanding job cultivating the enquiring hearts and minds of so many.

Royal Agricultural Society of NSW – Michael Millner

On behalf of the Council and Fellows of the Royal Society of Edinburgh I have the pleasure of sending warm greetings on the occasion of the 200th anniversary of the founding of the Royal Society of New South Wales.

Royal Society of Edinburgh – John Ball

As President of the oldest learned society in the United States (founded by Benjamin Franklin in 1743), it is my distinct honor and pleasure to welcome the Royal Society of New South Wales to the company of bi-centenarians. In today's world, where evanescence rather than permanence so often seems the order of the day, reaching a 200th anniversary is no small accomplishment.

American Philosophical Society – Linda Greenhouse

The Royal Irish Academy is delighted to acknowledge the achievements of the Royal Society of New South Wales and wishes the Society continued success in the future.

Royal Irish Academy – Mary Canning

I congratulate the Royal Society of New South Wales on the occasion of its 200th anniversary. The links between our academies go back all the way through those years, and throughout that time we have both been fortunate to have some exceptionally talented Fellows in common, from those involved in the founding of the Society through to national academy presidents in both our countries, Nobel Prize winners, and some of the leading scientists of the present day.

Royal Society – Sir Adrian Smith

Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, pp. 138–142. ISSN 0035-9173/22/020138-05

Presidential address at the Gala Dinner

Susan M Pond AM FRSN FTSE FAHMS

President of the Royal Society of New South Wales

Email: president@royalsoc.org.au

Abstract

Address by President Susan M Pond at the Royal Society of New South Wales Gala Dinner Celebrating 200 Years, in the Great Hall of the University of Sydney, 24 June 2022.

It is my privilege to address you tonight as President of the Royal Society of NSW. Celebrating a two-hundred-year milestone pales into insignificance compared to the long history of Aboriginal Australian and Torres Strait Islander peoples. Thank you, Aunty Ann,[1] for your warm welcome to Country.

Former Presidents, Current Council Members, Distinguished Fellows, Fellows and Members of the Society and your guests. Leaders in academia, government, business, and the not-for-profit sector. Andrew and Paula Liveris, who are not here tonight, but are kind sponsors of this dinner and here in spirit. My thanks to the University of Sydney for its generous support of this evening's celebrations, and to the hosts and guests, including students, at the tables graciously sponsored by eight of our State's Universities.

Members of the Society's dedicated Dinner Committee — Bruce Ramage, Wendy Enevoldsen Marian Kernahan, John Hardie, and designer, Virginia Buckingham — made every aspect, every last detail of this evening perfect: guest speaker, Dr Alan Finkel AC.

Tonight, we celebrate the Society's 200th birthday, one year late because of the pandemic.

No Society can boast such a long history unless it has deep connection with its members and the community, unless its values and work resonate deeply with what it means to be human, what it means to experience the magnificent wonder of being alive, what it means to explore all corners of knowledge and humanity with wide-eyed curiosity, what it means to meet extraordinary people who are unlocking the secrets of the world around us, and ourselves, and who are unlocking the potential of our own state and country. The Society summarises these 200-year-old attributes in the short phrase — *Enriching Lives through Knowledge and Inquiry*.

The names of the Society's founders from 200 years ago are still familiar. Brisbane, Barron Field, Goulburn, Wollstonecraft, Oxley, Berry to name a few. Their intent was to establish a Society with a view to inquiring into the various branches of physical science of this vast continent and its adjacent regions.

1 The dinner was welcomed to country by Wiradjuri elder, Aunty Ann Weldon, founding member of the NSW Aboriginal Children's Service, first female CEO of the Aboriginal Legal Service, and first CEO of the NSW Aboriginal Land Council.

Almost without exception these founding members were pastoralists, merchants, or professionals such as clergymen, lawyers, or medical practitioners. From the beginning, they also recognised the need to educate and inform the broader public about the achievements of science and organised regular gatherings for that purpose.

In 1866, when Queen Victoria granted Royal Assent to the Society, it was renamed The Royal Society of New South Wales. In 1881, the Society was incorporated by an Act of the New South Wales Parliament. The Act, which remains unchanged today, speaks to the broad purpose of the Society "the encouragement of studies and investigations in Science, Art, Literature and Philosophy."

The Society's Seal that you see in the booklet on your table was designed by Archibald Liversidge, who at the time of incorporation was Honorary Secretary of the Society. In Liversidge's words[2] "Most of the charges in the Seal have a double significance — they each represent one of the sections of the Society and have a symbolic meaning as well." Each section catered for a specialist interest, such as astronomy, geology, and literature and fine arts. I will leave it to you to examine the Seal more closely. Liversidge was Professor of Chemistry at the University of Sydney from 1874 to 1907, and the first Dean of Science at the University. His portrait hangs here in the Great Hall as do the portraits of several other past and present members of the Society.

As you read in your invitation to attend this dinner, while we are honouring the Society's past, we are looking to its future. It is my role to provide the yin — the story of our past — to our speaker Alan Finkel's yang, the yet to be written story. More about Alan later.

But attempting a history of the Society's 200-years in a few minutes is impossible. I choose instead to focus on the first 30 years of the Society's second century, from 1921, to parallel Alan's lift off in 2021.

1921 is apropos for several reasons. Qantas Ltd was founded in Winton, Queensland, in November 1920. Lawrence Hargrave, a gifted explorer, astronomer, and inventor was a longstanding member of the Society from for 38 years until his death in 1915. His important experiments with box kites proved basic theories of flight. He contributed 24 papers on his aeronautical work on airframes and engines to the Society's *Journal*. Your program contains an image of Hargrave and his flying machines in action. The Society holds several of his drawings in its collection.

1921 also has the parallel of being towards the end of the influenza pandemic which still stands as one of the greatest natural disasters of all time. The pandemic led to major demographic and social tragedy that compounded the disastrous consequences of World War I. It brought to the fore the same challenges to our health system and the same tensions in the Federation that we have just experienced with the COVID-19 pandemic. Thereafter, Australia lived through the Great Depression triggered by the October 1929 Wall-street stock-market crash.

Other notable events in this thirty-year timeline were: Douglas Mawson's Antarctic Expeditions (Mawson was awarded the Society's Clarke Medal in 1936); construction of the Sydney Harbour Bridge — the design of which owes so much to Society

2 https://royalsoc.org.au/images/pdf/RSNSW_Seal_History.pdf

Member John Bradfield; the Snowy Mountains Scheme; the introduction of the Salk vaccine for influenza; penicillin being made medically useful by Florey and Chain; World War II; and the beginning of the post-war baby boom and post-war immigration.

What a tumultuous thirty years! Alan, you have quite a challenge ahead of you to predict the next thirty!

How did the Society fare during this tumult and what influence did it have? I will recount just a few highlights.

In his Presidential Address[3] in 1921, James Nangle, architect and educationalist, wrote "Events arising out of the great war altered the aspect of many things, but perhaps most of all that of science organisations. It became apparent as the war went on that the very existence of nationhood depended on the efficiency with which scientific research was fostered and cared for."

Such sentiments had led to the Paris Peace Conference, which held formal meetings of the victorious allies in 1919 and 1920. Its aims were to establish the International Research Council, and for each participating country to establish a national one.

The Royal Society of NSW, as the senior scientific society in the country, was invited to convene the Australian conference and form a provisional Australian National Research Council (ANRC), which it did. When the ANRC was established formally in January 1921, it consisted of 100 members representing 22 branches of science. Many members of the Society were chosen as representatives. The ANRC was only disbanded in 1954 when it transformed into the Australian Academy of Science. Similarly, through the thinking and advocacy of its members, the Society contributed to the establishment in 1926 of the Council of Scientific and Industrial Research (now CSIRO).

The 28 September 1927 minutes of the Society's Council meeting quote a letter from the acting undersecretary of the NSW Premier's Department "Following upon the representations made by you on behalf of various scientific societies, I have to inform you that the Premier has approved of a block of land situated at the corner of Gloucester and Essex in the Observatory Hill area being made available for the erection of a building to house the Royal Society of NSW, the Institution of Engineers, the Linnean Society, the Australian Chemical Institute, the Wireless Institute, the British Astronomical Association, the Australian Association for the Advancement of Sciences and other similar societies."

Thus, was born Science House, which three Societies, the Royal Society of NSW, the Linnean Society, and the Institution of Engineers, built at their own expense. This collaboration shows the deep immersion of the Society in the development of NSW and Australia.

On 6 May 1931, at the height of the Great Depression, Professor Vonwiller reported in his Presidential address[4] that "It is fitting that I should commence my address by noting that it is the first meeting of the Society in its new home, Science House."

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3 James Nangle, Presidential address. The Repatriation Department's Vocational Training System for returned soldiers., *Journal & Proceedings of the Royal Society of New South Wales* 55: 1–48, 1921. https://www.biodiversitylibrary.org/page/41519222#page/35/mode/1up

4 Oscar Ulrich Vonwiller, Presidential address. *Journal & Proceedings of the Royal Society of New South Wales* 65: 1–36, 1931. https://www.biodiversitylibrary.org/page/46190173#page/35/mode/1up

The Society occupied Science House until the NSW Government, in its ambition to redevelop the Rocks, gave notice in 1970 of its intention to demolish the building.

The good news is that Science House still stands in all its glory thanks to the intervention of Jack Mundey and others to save the Rocks. The bad news is that our Society has led a nomadic existence ever since. Something that we are working to rectify.

On 26 June 1935, Council Minutes recorded, without any previous reference to the matter, that the Society had received a letter from Messrs Allen, Allen & Hemsley, stating that in their opinion there was nothing in the rules to prevent women from becoming members. Eleven women were admitted at the next two General Meetings, clearly because of pent-up demand.

When Arthur Penfold delivered his Presidential address[5] on 6 May 1936, he said, "Ladies and gentlemen, this is the first time in the history of the Society that the Presidential address has been delivered to ladies as well as gentlemen." Palaeontologist Dr Ida Brown, admitted in the first cohort, became the first woman to be elected President of the Society in 1954.

In enabling women to become members, the Society was ahead of its time. Older organisations were slower. The Royal Society of London did not elect its first women until 1945. The Royal Society of Edinburgh reached this milestone in 1949. The 279-year-old American Philosophical Society elected its first female president, Linda Greenhouse, in 2016. You will see a birthday message from Linda in the booklet on your table.

Speaking of which, I hope you all had the opportunity to read some of the birthday wishes the Society has received from kindred organisations and individuals. They were on display in the Chau Chak Wing Museum earlier tonight, and we will also make them available later. We were delighted to receive so many. I only single out one, from Sir David Attenborough, and I quote "May I send my warmest congratulations to the Royal Society of New South Wales on reaching the two hundredth anniversary of its foundation. No learned society in the world can ever have had the sudden privilege and responsibility of describing and investigating a whole new division of the plant and animal world; and none in my experience has been more generous in guiding visitors from overseas around the marvels of the continent about which it has become so authoritative."

In 1940, in the shadow of WWII, Halcro Wardlaw noted in his Presidential address[6] that because of the "uncertainty in world conditions" the Society had written to the Government offering its services and noting that several of its members were already being consulted individually to assist Government Departments.

5 Arthur de Ramon Penfold, Presidential address. *Journal & Proceedings of the Royal Society of New South Wales* 70: 1–38, 1936. https://www.biodiversitylibrary.org/page/46153973#page/39/mode/1up

6 Henry Sloane Halcro Wardlaw, Presidential address. *Journal & Proceedings of the Royal Society of New South Wales* 74: 1–41, 1940. https://www.biodiversitylibrary.org/page/46186648#page/19/mode/1up

The 1946[7] and 1947[8] Presidential addresses, largely devoted to the consequences of the dropping of the atomic bombs in Japan, led to a more intense drive to enlist into Society membership citizens who were not scientists but who embraced wider societal and ethical concerns. The Society's current membership reflects this broader sweep of interests and experiences. We are all the richer for it.

As we dine tonight, we can find many recent parallels with the times in 1921. Not the least of them are the COVID-19 pandemic, tumultuous politics abroad and here in Australia, and fundamental challenges such as climate change and social inequalities. We look forward to the Society playing its part in addressing these challenges. It is in the unique position of possessing enormous intellect and presenting fact-based views across a broad range of topics. I look forward to receiving advice from you about the Society's future direction.

We all look forward to hearing from our after-dinner speaker, Dr Alan Finkel, AC, who will begin that conversation. Alan is a neuroscientist, engineer, and entrepreneur. As Australia's Chief Scientist from 2016 to 2020, Alan led the National Electricity Market Review, the development of the National Hydrogen Strategy, and the panel that advised the Australian Government on the 2020 Low Emissions Technology Roadmap.

Currently Alan is Chair of Stile Education and the Australian Government's Technology Investment Advisory Council. He is also Special Adviser to the Australian Government on Low Emissions Technologies.

Alan, thank you so much for celebrating the Society's 200 years with us. We will be slightly heavier when we board your flight to the future after the main course.

7 Adolph Bolliger, Presidential address. *Journal & Proceedings of the Royal Society of New South Wales* 80: 1–13, 1946. https://www.biodiversitylibrary.org/page/46153368#page/285/mode/1up

8 Francis Lions, Presidential address. *Journal & Proceedings of the Royal Society of New South Wales* 81: 1–11, 1947. https://www.biodiversitylibrary.org/page/46175755#page/31/mode/1up

Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, p. 143. ISSN 0035-9173/22/020143-01

Welcome address

Her Excellency, the Honourable Margaret Beazley AC QC

Governor of New South Wales, Patron of the Royal Society

Good evening to you all.

As Patron of the Royal Society of New South Wales, I would have enjoyed joining you this evening for your 200th Anniversary Dinner. I know this event has been a while coming with all the delays and adjustments required over the past twelve months but here you are ready to celebrate.

As you are watching this, Dennis and I are in the Northern Hemisphere singing the praises of New South Wales and promoting engagement in London, Paris and Belgium.

On the occasion of this anniversary event I must acknowledge my predecessor Governor Thomas Brisbane, the 6th Governor of New South Wales, the first President of the Philosophical Society of Australasia, which was the precursor society of the Royal Society of New South Wales.[1]

The relationship with Governors has remained constant over your 200 years and I am honoured to continue that tradition.

Government House has been proud to host the annual Royal Society and Learned Academies Forum and to collaborate on the virtual and recently live and livestreamed editions of Ideas@theHouse. These important platforms of discussion promote not only creative thought and intellectual engagement, but foster community and connection.

One thing that has struck me about the Society over the past two years is that for an organisation with such a rich history, you are constantly looking forward. That is reflected in Dr Alan Finkel's after-dinner address topic tonight "All aboard — choose your flight to the future."

Congratulations to the Society for all you have done throughout your history to enrich lives through knowledge, and all that you continue to do to contribute to the intellectual life of the State of New South Wales.

1 https://www.royalsoc.org.au/about-us/history

Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, pp. 144–151. ISSN 0035-9173/22/020144-08

After-dinner speech: Choose your flight to the future

Alan Finkel AC FAA FTSE FAHMS

Special Adviser to the Australian Government on Low Emissions Technologies

E-mail: alan.finkel@industry.gov.au

Abstract

This is the after-dinner address to the Gala Dinner on 24 June 2022, celebrating two hundred years since the foundation of the Royal Society of New South Wales in 1821.

Ready to fly

Earlier this evening we heard an eloquent description from the Society President, Susan Pond, of the significant contributions of the Royal Society of New South Wales. And what a high-impact journey it has been over its 200-year existence!

The last time I spoke at this Royal Society, many years ago, my topic was the future of work.[1] Other pundits in the symposium predicted that by now, automation would have destroyed the jobs market.

In contrast, I predicted that despite the inexorable changes, demand for jobs would stay strong. I was right! So, I have earned the privilege of taking you on a journey into the future.

Speaking of journeys, I recently went on my first international flight since COVID-19. Looking out the window as we started our descent into Los Angeles, I saw proof of the historical progress.

From 30,000 feet, the highways and traffic, the high-rise buildings and the agricultural fields completed a tapestry unimaginable 200 years ago.

I was reminded of a story that John Bertrand, Australia's famous America's Cup captain, told me of the day in 1983 when he was at the White House to be awarded the prestigious trophy.

President Ronald Reagan's Chief of Staff, James Baker, told John about the time the President flew to Moscow for nuclear disarmament talks.

President Reagan sat for hours thoughtfully looking out the window as they flew over Russia and descended into Moscow.

On landing, Reagan turned to Baker, "James, the economy of the USSR is not nearly as strong as they claim."

"Why do you say that Mr President?"

"Because there are hardly any trucks on the highways."

Reagan was right. The USSR's self-vaunted, centrally managed economy was near collapse. President Reagan got to fly on the very special aeroplane known as Airforce One.

Tonight, thanks to an arrangement between the Royal Society of NSW and Qantastic Airlines, I can offer you an extraordinary flight on another very special aeroplane.

The clue to the uniqueness of this offer is the flight plan: we depart Sydney, and we arrive in Sydney.

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1 Alan Finkel (2015) Reflecting on the future of work in Australia: pessimism, optimism and opportunities, *Journal & Proceedings of the Royal Society of NSW*, 148: 125–133.

We take off at 10 PM tonight and we arrive at 10 AM tomorrow, but in 2052!

Thirty years from now.

That's at least ten federal elections you'll miss.

No passport or visa required — all you need is a sense of adventure.

So, please join me — you will not have another chance until the 300th gala dinner of the Royal Society of New South Wales.

First flight

Take off.

More than eleven hours and a good sleep later, the pilot announces, "Passengers, we will soon be landing in Sydney, in the year 2052. The time is exactly 9:35 AM; please set your watches. Unfortunately, when we land, your smartphones will not work on the 12G network."

"Look," Peter Shergold[2] observes, pointing out the window. "Huge swathes of burned forests stretching out in all directions. And the highway traffic is surprisingly light."

"I wonder why?" the Honourable Justice Brian Preston[3] ponders, just loud enough for me to hear.

After a smooth landing, we meet our guide at the terminal, a friendly young man named Tim.

As he directs us to the autonomous van that will take us to the Opera House, Tim says. "It will be my honour to answer any questions you may have."

"Climate change," the Honourable Gabrielle Upton[4] inquires. "It's now two years past 2050. Did the world get to net zero? Did Australia?"

"Neither," answers Tim. "While there was progress in the 2020s, Australia, Europe and America didn't manage to scale up fast enough. In Europe and America, the failure was a consequence of the pan-European war that began with Russia's invasion of Ukraine."

"In Australia, industry and government failed to engage local communities and landholders, making the construction of new transmission lines and wind farms difficult."

"Meanwhile, operators could not afford major maintenance of their coal fired power stations and they started to fail. Electricity prices skyrocketed. There were riots."

"The government wound back its targets and continued to support oil for transport and coal for electricity. Progress has been slow."

"What about health?" asks Attila Brungs.[5]

"Not great," says Tim. "In particular, the H20N35 bird flu pandemic that started in 2035 was a disaster. In just six years, 150 million people died worldwide. Hospitals were overrun, and the global economy was set back a decade."

"Because investment in science had been at historical lows beforehand, scientists had little to build on. Disinformation led to protests, and blockades of vaccine facilities in most countries."

"It took more than four years before the first truly effective vaccine appeared."

"Antibiotics?" asks Peter Baume.[6]

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2 Peter Shergold, AC FRSN, Chancellor, Western Sydney University.

3 Justice Brian Preston, the Hon, FRSN, Chief Judge, Land and Environment. Court, NSW.

4 Gabrielle Upton, the Hon, Member for Vaucluse; Parliamentary Secretary for Premier.

5 Attila Brungs, FRSN, Vice-Chancellor UNSW.

6 Peter Baume, AC DistFRSN, Emeritus professor, medicine.

"We never found new classes of antibiotics and the traditional antibiotics are no longer effective," replies Tim. "Nowadays, infection is a leading cause of death. If you're infected, it's not pretty."

"How's the Royal Society of New South Wales?" asks Susan Pond.[7]

"Never heard of them," replies Tim.

"Wait! Stop! I want to go back," Susan cries.

"I agree!" the Honourable John Dowd[8] exclaims, and everyone chimes in, "Back to the airport! Back to the airport!"

At the departure lounge, our pilot greets us anxiously.

"Oh! I'm so glad you're back early — there's been a terrible mistake! An error in the flight computer sent us to the *wrong* future!"

We rush aboard and take off on our return journey. Hours later, we arrive at Sydney just before midnight on Saturday the 25th of June 2022.

As we disembark, a Qantastic Airlines flight steward apologises profusely for the error and gives each of us a free ticket for another flight to the future.

"But be quick," she says. "Departure is in 30 minutes."

Second flight

Take off.

More than eleven hours and a good sleep later, the pilot announces, "Passengers, we will shortly be landing in Sydney in the year 2052. The time is exactly 11:35 AM; please set your watches. Unfortunately, when we land, your smartphones will not work on the 12G network."

"Look," Anne Maria Nicholson[9] observes, pointing out the window. "Lush forests and fields of farmland stretching out in all directions. And the highway traffic is heavy."

"Remarkably so," John Hardie[10] concurs.

After a smooth landing, we meet our guide at the terminal, a friendly young woman named Tina.

As she directs us to the autonomous van that will take us to the Opera House, Tina says. "It will be my honour to answer any questions you may have."

The van accelerates rapidly along the entrance to a freeway filled by a phalanx of sedans, trucks and one-person bubble cars moving very fast, with hardly a space between them.

"*We're going to crash!*" I gulp. But suddenly, an opening appears, and we slip in, snug between a giant truck and a midsize sedan.

"Oh, I'm sorry," says Tina, seeing us turn pale. "You're our first visitors from the past. I should have realised you didn't have smart cars and convoys in the 2020s. A smart convoy would never allow an accident to happen."

"Climate change," Saul Griffith[11] inquires, changing the subject. "It's now two years past 2050. Did the world get to net zero? Did Australia?"

"Oh yes," says Tina. "Australia aced it. There was great progress in the 2020s, which built momentum and ensured progress in the 2030s, too."

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7 Susan Pond, AM FRSN, President, RSNSW.

8 John Dowd, the Hon, AO FRSN, International Commission of Jurists Australia.

9 Anne Maria Nicholson, FRSN, author, journalist, Arts.

10 John Hardie, AM FRSN, Past President RSNSW.

11 Saul Griffith, FRSN, Author of *The Big Switch: Australia's Electric Future* (Black Inc., 2022).

"What worked best? Here, and overseas?" asks Ross Hynes.[12]

"Well, here the 2050 net zero target was legislated, and everyone worked to achieve it," Tina replies.

"Also, the designation of the 2032 Brisbane Olympics as the Sunshine Games had a galvanising effect. Heating, lighting, and transport in the stadiums and athletes' villages were powered by solar and wind, or hydrogen from renewables."

"Had you heard of hydrogen back then?" Tina asks.

"Actually, ahem, yes!" I mutter, ironically.[13]

"While the Sunshine Games started as a marketing slogan," Tina continues, "it quickly became an inspiration. Science had shown the need to reduce emissions fast. And since nearly three quarters came from coal, oil, and natural gas to produce energy, everyone rightly focussed on the energy system."

"Through intense investment in solar and wind farms, transmission lines to connect them, rooftop solar, batteries and a sophisticated digital control system for the electricity grid, we developed a reliable zero emissions electricity supply."

"As it was increasingly deployed, we were able to progressively switch off the coal and gas generators."

"It's a different world, now," Tina continues. "Some historians say that humanity has transitioned from the Industrial Age to the Electric Age."

Shifting her attention beyond the energy sector, Tina explains that eliminating other emissions was difficult. These included carbon dioxide from cement production, and methane from landfill and from agricultural waste such as animal manure and rice stalks.

"The biggest challenge was methane from belching cows and sheep," she reflects.

"Environmental movements to 'go vegetarian' or 'go vegan,' and even the 'eat kangaroo' movement, made small contributions but never achieved critical mass."

"Two major innovations solved it," Tina recalls. "One was the introduction of seaweed as a food supplement to suppress methane burps — sounds too good to be true, but it works."

"The other was synthetic meat that tastes just as good as nature's original."

"My grandfather, Alan Finkel, told me he had his first synthetic burger in 2022. I think he referred to it as an Impossible Burger, and he really enjoyed it. He said he expected it to taste like a veggie burger, but it tasted like the real thing!"

"Anyway, Australia achieved net zero in 2047."

"Europe got there early too, while the U.S. and Canada are almost at net zero, as is most of South America and Africa. China and India will probably make net zero by the end of this decade."

Pointing outside the van, Tina calls out: "Do you recognize that?"

"You bet," replies Pamela Griffith.[14] "The Opera House. But there are so many stunning new buildings."

"Look at that one leaning out over the water without support! It must be 100 storeys high and cantilevered a hundred

12 Ross Hynes, President, Royal Society of Queensland.

13 Alan Finkel was the Chair of the Australian Government's Hydrogen Strategy Group in 2018.

14 Pamela Griffith, FRSN, artist; mother of Saul Griffith.

metres! What construction material is strong enough to support that!"

"Nothing from 2022," Tanya Monro[15] offers, "they must have invented metal alloys far stronger than anything we had."

"The architecture is amazing," Tanya continues, "and it's terrific to see so many leafy green zones. Which makes me want to know about global warming. Tina, what about global temperatures?"

"That's not so good," Tina replies. "The global average is now two degrees above the preindustrial baseline. There was simply too much inertia in the system."

"The number of fire hazard days is well above the average of last century, and flooding is more common," she adds.

"On the positive side, new building codes have improved the thermal performance of houses, and ultra-efficient heat-pumps help people to live comfortably year-round."

"Also, we are very excited about the roll out of the machines that remove carbon dioxide from the air so that it can be buried permanently underground. The cost has fallen dramatically, and in a century, we'll probably reduce atmospheric carbon dioxide by at least 50 parts per million, to what it was in the 1990s."

"You know," I say, "in 2022 Australia was already a solar electricity superstar. The main impediment to expanding wind and solar was that landowners fought against transmission lines carving up their properties. How did you solve that?"

"Well, we took advice from the social scientists," said Tina. "Based on their research, companies learned to work with local communities to minimise the impact and offer fair compensation. Occasionally, short sections of the transmission lines went underground. Problem solved."

"Wow," I say. "Social scientists! Who would have thought?"

"The roll-out of solar and wind electricity boomed," continues Tina. "And so did industry. Low-cost electricity helped boost manufacturing along the east coast of Australia."

"What's more, renewable hydrogen and ammonia, and zero emissions iron and aluminium, became successful exports that replaced our declining coal and natural gas exports."

"Other resources boomed as well. Last year, in 2051, we had record exports of copper, iron, lithium, nickel, graphite, manganese and rare earths."

"Land use challenges do remain, but companies have learned to listen to environmental and social scientists, and work with local and indigenous communities. The companies provide sustainable local jobs and restore abandoned sites to good condition."

"Australia's sovereign wealth fund is over $2 trillion. Politicians fight over how to spend the interest," she grins.

Tina goes quiet, giving us time to absorb it all. The cars and trucks around us are silent and driverless, all battery or hydrogen electric. Then, suddenly, a familiar and really annoying noise grows louder and goes screaming past us.

"A motorbike exhaust!" Paul Jeans[16] marvels. "How can that be?"

Tina grins: "There's a loophole in the zero emission laws. That motorbike is running on

15 Tanya Monro, AC, Chief Defence Scientist.

16 Paul Jeans, FRSN, Chancellor, University of Newcastle.

synthetic jet fuel, same as aeroplanes. It has zero carbon dioxide emissions but massive audio emissions!"

"So, Tina," asks Barney Glover,[17] "are you saying that science, engineering, logic and planning, prevailed over emotion, selfishness, greed and ideology? Who would have thought?"

"Yes," says Tina. "Things worked out better than expected. But there have been setbacks, like the H20N35 bird flu pandemic. It raged for 10 months from August 2035."

"It came on faster and harder than the COVID-19 pandemic of your time, it was incredibly contagious."

"More than five million people died worldwide in the first two months. But by then its genome had been sequenced by labs in Parkville, Suzhou, and Oxford, and the world's 17 mRNA factories started to ramp up vaccine production."

"The global death rate peaked at month four, and within 10 months it was effectively zero."

"Speaking of medicine: in your time, you were worried about antimicrobial resistance, am I right? Well, new strains of antibiotics were developed, the most successful being one that destroys bacterial membranes. The first was approved in 2026 and was an immediate success against golden staph and vancomycin-resistant bacteria."

"These new classes of antibiotics allowed older antibiotics to be used less frequently, so resistance rates fell."

"Something from your time that *didn't* work were mind-machine interfaces — you know, where you drill a hole through the skull and implant electrodes. Testing in animals showed the brain rejected the electrodes within a few weeks. And besides, the Silicon Valley companies developing them couldn't find a single human volunteer for the brain surgery."

"What's happening in the rest of the world, Tina?" asks Duncan Ivison.[18]

"Well, the collapse of the United States was averted by constitutional reforms following the Florida riots. They copied compulsory voting from Australia, thereby minimising unrepresentative, radical outcomes. And they adopted the two-round presidential voting system used in France, thereby ensuring the people of America elected the presidential candidate truly preferred by the majority. Who would have thought?"

"Social media manipulation by criminals, enemy states and corporations got really bad for a while, until the Banana Six smartphone came along. It had a super powerful chip that did all the AI processing on the phone itself. Now no-one has to share location data or searches, so targeted advertising doesn't work."

"Eventually, most countries passed laws making companies responsible for the content of messages on their platforms. Defamation lawsuits spread like wildfire, and social media companies went bankrupt. Those that survived were transparent and responsible."

"Tell us more about science," asks Veena Sahajawalla,[19] "has it thrived, or suffered?"

"Depends on who you ask," Tina says. "Federal Government funding for R&D is

17 Barney Glover, AO FRSN, Vice-Chancellor, Western Sydney University.

18 Duncan Ivison, FRSN, DVCR University of Sydney until April 2022; philosopher.

19 Veena Sahajwalla, FRSN, AAS Council Member.

3.5% of GDP, which is probably double what it was in 2020."

"And the states?" asks, Christina Newman,[20] "are they investing, too?"

"I don't know about the other states," replies Tina, "but back in your time the New South Wales Government released a 20-year R&D roadmap, and, I'm not sure, but I think that successive governments have updated it every five years since then."

"What about scientific advice to government?" asks Kathy Belov,[21] as she glances up at a flock of school students swooping overhead in autonomous quadcopters.

"There's a system of advice to ministers, including a Rapid Research Information Forum, plus short and long-form reports produced on-demand. They're all well-funded and publicly available."

"And the Chief Scientist?" Cathy Foley[22] tentatively asks.

"Do you mean the Chief Scientific Advisor to the Prime Minister? She's listened to and well-funded. Very popular, too."

"Hallelujah!" whispers Cathy, with a quiet smile she carries for the rest of the trip.

"Tina," asks Brigid Heywood,[23] "tell us about universities. Have they survived, or were they replaced by a single, online global mega-university?"

"Somewhere in between," replies Tina. "There *are* online mega-universities, using artificial intelligence instructors to each teach 20 million students or more. But there are only three worldwide, and they mostly specialise in second degrees."

"Could you elaborate?" Brigid probes.

"Well, young people doing their first degree go to university as much for the social experience as the learning experience, and online didn't give them that.

"Most universities have returned to fundamentals, like enforcing prerequisites and creating enticing campuses that encourage students to attend and study."

"They also teach students to use their BS detectors to filter everything they read and hear."

"There are some good things happening in schools, too. For example, students are taught analytical thinking, so they're able to distinguish evidence-based theories from conspiracy theories."

"And every Australian school has a subscription to *Cosmos* magazine, with the result that students are well aware of the role of science in the world around them."

Wilson da Silva blushes,[24] proudly.

"What about royal societies?" asks Susan Pond, in anticipation. "Does the Royal Society of New South Wales still exist?"

"Interesting question," replies Tina. "Were you involved way back then?"

Susan winces, then nods.

"They're doing well," continues Tina. "Their speciality is live presentations by charismatic experts,' she explains. "The experts tour the capital cities, hosted by the local royal society. It turns out that audiences enjoy attending live presentations much more than watching speakers online."

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20 Christina Newman, Deputy Director, Office NSW Chief Scientist.

21 Kathy Belov, AO FRSN, Professor in comparative genomics, University of Sydney.

22 Cathy Foley, AO PSM FRSN, Australia's Chief Scientist.

23 Brigid Heywood, Vice-Chancellor UNE.

24 Wilson da Silva, Co-founder and former Editor-in-Chief, *Cosmos* Magazine.

"Things have worked out much better than I expected," observes Robyn Williams.[25] "I'm so glad I took this flight. As an authority on the 21st century, Tina, what do you think worked best?"

"Mr Williams, before I reply, can I say how much I enjoyed my undergraduate class, called *Lessons from the ABC Science Show 101*? I'm so honoured to meet you!"

Robyn's cheeks redden.

"Anyway, in my opinion," continues Tina, "what worked best was the realisation in the late 2020s that pursuing perfection doesn't deliver."

"Another contributor was the *National Science Meets Economics* conference in 2027, where scientists accepted that scientific advice has to co-exist alongside economic considerations, while economists accepted that economics advice has to factor in science. From then on, politicians could listen to the experts without having to choose sides!"

"You are so well informed, Tina," observes Mark Scott.[26] "Where did you learn so much?"

"I studied modern history at the University of Sydney," she replies, and Mark smiles.

"Ahem, may I have your attention? Your attention please!" says a hologram of the pilot, suddenly appearing before us. "Passengers, we need to return to 2022 soon, before the time portal closes. If we are too slow, we'll be stuck in 2052!"

Sitting in the seat next to me, Emma Johnston,[27] white as a ghost, whispers: "Alan, I think I'll stay. This future is fantastic."

I tell her I'm tempted to do the same.

"But Emma, we can't. We need to go back to 2022, to ensure this future happens!"

Emma pauses for a moment. "You're right, Alan. There's a lot to do!"

We sit silently, pensively, on the way to the airport.

Disembarking in the Present

We rush aboard and take off on our return journey.

"Alan," says Jude Rae,[28] 12 hours later as we disembark the Qantastic Airlines aeroplane under a sunny Sydney sky on Sunday, 26 June 2022. "I put my smartphone on flight mode while we were in the future, and I took lots of pictures. Let me show you."

But they're all blank.

Conclusion

Distinguished guests, my challenge to each and every one of you is to help deliver the future we all want.

Miracles don't just happen, they are the result of intelligent, concerted effort.

May the Force be with you.

And may the Force bring continued success to the Royal Society of New South Wales.

25 Robyn Williams, AO, science journalist and broadcaster.

26 Mark Scott, AO FRSN, Vice-Chancellor, University of Sydney.

27 Emma Johnston, AO FRSN, incoming DVCR, University of Sydney, July 2022.

28 Jude Rae, FRSN, artist.

Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, p. 152. ISSN 0035-9173/22/020152-01

Welcome address

His Excellency, David Hurley

Governor-General of Australia

I am delighted to provide this message of congratulations to the Royal Society of New South Wales on the occasion of your Bicentenary Dinner.

As a former Patron of the Royal Society I thoroughly enjoyed the many occasions in which we gathered to consider some of the big issues of the day.

For 200 years the Society has enriched the lives of the people of New South Wales and the wider nation through the pursuit of knowledge.

It is a remarkable achievement and a credit to all members, past and present.

Tonight's Anniversary Dinner is an occasion to celebrate your many achievements and to enjoy the fellowship of members.

As Patron of Royal Societies of Australia — enjoy the celebrations and Happy Birthday!

Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, pp. 153–159. ISSN 0035-9173/22/020153-07

Greetings from around the world[1]

Friday 24 June 2022 was an extraordinary milestone for the Society. Members and guests, numbering 274, before repairing to the University of Sydney's Great Hall, enjoyed pre-dinner drinks in the surroundings of the nearby Chau Chak Wing Museum, where a special exhibition of their holdings relating to the Society was on display. Also featured on two screens was a selection of birthday wishes from organisations and individuals from around the world.

The Society's archives have now been greatly enriched especially by birthday messages received. Of particular note is the message received from Sir David Attenborough:

> May I send my warmest congratulations to the Royal Society of New South Wales on reaching the two hundredth anniversary of its foundation. No learned society in the world can ever have had the sudden privilege and responsibility of describing and investigating a whole new division of the plant and animal world; and none in my experience has been more generous in guiding visitors from overseas around the marvels of the continent about which it has become so authoritative. — *David Attenborough*

Below are the messages we received from organisations older than we are. We are privileged to be joining the 200 Club.

American Philosophical Society

As president of the American Philosophical Society, the oldest learned society in the United States (founded by Benjamin Franklin in 1743), it is my distinct honor and pleasure to welcome the Royal Society of New South Wales to the company of bi-centenarians.

In today's world, where evanescence rather than permanence so often seems the order of the day, reaching a 200th anniversary is no small accomplishment. Your history of two hundred years of contribution to human knowledge is to be celebrated — indeed, it is to be cherished.

I send greetings to your president, Dr. Susan M. Pond. May our two societies continue to thrive for centuries to come.

With my personal best wishes,

Linda Greenhouse
President

The Royal Agricultural Society of NSW

From one bi-centenarian to another, on behalf of the Royal Agricultural Society of NSW, I'd like to say congratulations on reaching this tremendous milestone and we share with you the enormous sigh of relief and proud sense of accomplishment and achievement.

It is an exclusive club, not only those of us who have reached two hundred years but also have had a positive impact shaping the state of New South Wales. Drawing on the who's who of society in the new colony we share a few common founders — among them Barron Field and Sir Thomas Brisbane, as well as a dedication to sharing knowledge and ideas, and enriching the lives of many. Whilst we have maintained a staunch dedication to safeguarding the agriculture of the state, you have done an outstanding

1 This is based upon three pieces by Bruce Ramage (Hon. Sec.) in the Society's *Bulletin*s of September, October, and November/December 2022.

job cultivating the enquiring hearts and minds of so many.

Mr Michael Millner
RAS President

The Royal Society of Edinburgh

Dear President,

On behalf of the Council and Fellows of the Royal Society of Edinburgh I have the pleasure of sending warm greetings on the occasion of the 200th anniversary of the founding of the Royal Society of New South Wales.

With best wishes,

Professor Sir John Ball, PRSE FRS
President

Royal Irish Academy

Dear Dr Pond,

I write on behalf of the Council, and Members of the Royal Irish Academy to offer warmest congratulations and best wishes to the Royal Society of New South Wales as it celebrates its bicentenary. Your Royal Society has much to be proud of, and it is fitting that you should celebrate accordingly.

The Royal Irish Academy, established in 1785, is Ireland's leading body for the promotion of the humanities, social sciences, science and engineering. As an all-island and independent body, it promotes academic discourse and policy development and analysis.

Ireland has had a historic and mutually beneficial association with Australia. The Royal Irish Academy benefits from its associations, interactions and collaborations with sister academies and values this fraternity in an increasingly unstable world.

The Royal Irish Academy is delighted to acknowledge the achievements of the Royal Society of New South Wales and wishes the Royal Society continued success in the future.

Regrettably the Royal Irish Academy will be unable to be represented at your Bicentennial Dinner. Please enjoy this historic event.

Dr Mary Canning MRIA
President

The Royal Society

On behalf of the Royal Society of London, I write to congratulate the Royal Society of New South Wales on the occasion of your 200th anniversary. The links between our academies go back all the way through those years, and throughout that time we have both been fortunate to have some exceptionally talented Fellows in common, from those involved in the founding of the RSNSW through to national academy presidents in both our countries, Nobel Prize winners, and some of the leading scientists of the present day. From one Royal Society to another, we congratulate you once again on reaching this important milestone, and wish you every success for the future.

Best wishes

Sir Adrian Smith
President, Royal Society

Messages from other organisations

Royal Society Te Apārangi of Aotearoa New Zealand

The Council of the Royal Society Te Apārangi of Aotearoa New Zealand passes on its heartfelt congratulations to the Royal Society of New South Wales on its bi-cen-

tenary. We wish you well on your quest to continue enriching lives through knowledge over the next 200 years to address the many new challenges and opportunities ahead.

We look forward to working in tandem with the RSNSW to explore, discover and share the use of this new knowledge to ensure a brighter future for all.

E kore e ngaro; he takere waka nui.
(We will never be lost; we are the hull of a great canoe)

Ngā mihi nui, nā

Brent Clothier FRSNZ
President, Royal Society Te Apārangi

Academy of the Social Sciences in Australia

Congratulations to the Royal Society on 200 years advancing knowledge and scholarship in the Sciences, Arts, Social Sciences and Humanities. The Academy of the Social Sciences in Australia looks forward to continuing its strong and active association with the Society across a broad range of issues.

Professor Richard Holden FES FASSA
President

The Royal Society of Queensland

It is very easy for Queensland and New South Wales to set aside any traditional rivalry when celebrating the birth of The Royal Society of New South Wales. For it shares its early story with The Royal Society of Queensland.

When inviting Queensland to contribute a message, your President Dr Susan Pond wrote, 'In 1821, Sir Thomas Brisbane … founded the Philosophical Society of Australia to which the Society traces its origins.' We have in common, much more than the name Brisbane. Queensland was a part of New South Wales until 1859 and in that year The Philosophical Society of Queensland was founded, taking its name from the New South Wales parent, and continuing in unbroken succession the Enlightenment tradition of independent scholarly enquiry that has been the foundation of our two organisations since their origin. As the word 'philosophy' shifted its meaning over the years, the Queensland Society as with New South Wales changed its name and sought Royal patronage, which in itself was an acknowledgement of a scholarly tradition dating back to the foundation in 1660 of the Royal Society of London.

It is possible to envisage a day when the adjective 'Royal' no longer resonates with contemporary society, but I cannot envisage a day when we can dispense with the need for an institution dedicated to independent curiosity-led and evidence-led experimentation, discovery and analysis while importantly also recording local science history. As the proliferation of Internet sites conveying misinformation and disinformation attests, our wider society more than ever needs to respect knowledge and respect those who generate and disseminate it.

Your foundation is our foundation; for the first 38 years your history was our history; and your celebration of your origin is our celebration too. Congratulations and best wishes on achieving 200 years! May the Royal Society of New South Wales successfully navigate the next century effectively *enriching lives through knowledge*.

Dr Ross A. Hynes
President

CSIRO

Congratulations to the Royal Society of New South Wales on two centuries of knowledge and intellectual contributions for the betterment of all Australians.

For more than 100 years, CSIRO has proudly stood shoulder to shoulder with the Royal Society to help guide our nation to a better future. Our organisations are both driven by the transformative power of science and technology, and by a fierce dedication to Team Australia.

The role of science, knowledge, and collaborative innovation has never been more critical to unlocking a better future for everyone. On behalf of your National Science Agency, CSIRO, I want to thank you for your partnership, dedication and continued leadership in pursuit of that future.

Dr Larry Marshall
Chief Executive

Geological Society of Australia

The Geological Society of Australia would like to congratulate the Royal Society of New South Wales on its 200th Anniversary. The Royal Society is an important learned academic society that contributes to open debate on scientific issues of relevance to society with a multidisciplinary lens. It celebrates scientific achievements and provides a forum for open and honest debate, and brings together scientists from diverse employment and discipline backgrounds. The 200-year anniversary is a testament to the standing the society has in the New South Wales and Australian scientific community.

Professor Peter Betts
President

Royal Society of South Australia

On behalf of the Royal Society of South Australia, I sincerely congratulate the Royal Society of New South Wales to their Bicentenary and 200 years of achievements as a learned society in Australia. The RSNSW has been foundational for the advancement of knowledge in Australia and has to be applauded for its contributions to sciences and society at large. We wish you all the best to continue the vibrant, inspirational activities.

Professor Sabine Dittmann
President

NSW Minister for Science, Innovation and Technology

The Royal Society of New South Wales (RSNSW) brings together some of Australia's most influential leaders and scholars (including four Nobel laureates) to discuss the big issues, underpinned by the key values of evidence, diversity and inclusion.

Being able to celebrate 200 years is an incredible milestone and testament to the sustained excellence of the RSNSW and its ongoing contribution to the wellbeing of NSW, Australia and the world.

With the NSW Government having just launched its 20-year R&D Roadmap to boost our research and development capabilities, we could not ask for a better representation of our world-leading capacity to produce, share and apply knowledge than the RSNSW. Here's to the next 200 years.

The Hon. Alister Henskens SC MP
Minister for Science, Innovation and Technology
Minister for Skills and Training

NSW Chief Scientist & Engineer

The Office of the Chief Scientist & Engineer (OCSE) celebrates this landmark year for the RSNSW. The RSNSW's mission to provide authentic and authoritative information across a diversity of sectors is more critical than ever as we face some of humanity's greatest challenges.

The RSNSW is an invaluable resource to the NSW Government, bringing together leaders in academia, business, government and the not-for-profit sector, and providing expertise in science, engineering and many other disciplines.

The NSW Government, through OCSE, is proud to sponsor the RSNSW and support its continued contribution to the enrichment of lives through knowledge and enquiry.

Professor Hugh Durrant-Whyte
NSW Chief Scientist & Engineer

Australian Academy of the Humanities

I write on behalf of the Council and Fellows of the Australian Academy of the Humanities to offer our warmest congratulations as you celebrate the 200th anniversary of the Royal Society of NSW.

This remarkable milestone reflects the enduring importance of the Society as a trusted and respected Australian institution dedicated to the pursuit of knowledge. It also signifies an organisation that has successfully adapted to reflect the changing needs of society and the science and research endeavour.

We are particularly delighted to see an increasing number of leading humanities scholars among the Society's membership, and to have played a role in supporting the rich and stimulating multidisciplinary forums on issues of national importance which have become a hallmark of the Society's work.

Once again, our congratulations on reaching this significant milestone.

Emeritus Professor Lesley Head FASSA FAHA
President

The Royal Society of Canada

On behalf of all members of the Royal Society of Canada I would like to send our very best wishes to The Royal Society of New South Wales on this very special occasion. While not present in person we are with you in spirit.

We congratulate you for your contributions over the last 200 years and wish you every success in your future endeavours. There is no doubt that organisations such as the RSNSW will play an important role in addressing important societal issues as we move forward.

Professor Jeremy N. McNeil, CM, FRSC
President

The Royal Institution of Australia

On behalf of the Royal Institution of Australia, we extend to the Royal Society of NSW our congratulations on your milestone of 200 years of contribution to the promotion of philosophical and scientific discourse and discovery in Australia.

The Royal Institution of Great Britain was founded by Sir Joseph Banks in his home to promote science, particularly his discoveries in Australia and in July 1867

when you become the Royal Society of NSW, I believe we became kinsmen.

On this special occasion we celebrate your achievements and look forward to your future.

Peter W Yates AM
Chairman

Distinguished Fellows

Peter Baume AC

One learns wonderful things in the Royal Society of New South Wales, things that one would never otherwise consider learning. The people are a delight to know and are so diverse. May the third century be as rich and rewarding as the last two have been.

Robert Clark AO

As a multidisciplinary learned Society underpinned by the principles of a liberal democracy, RSNSW has over its 200-year history been a forum for the free exchange of ideas advancing a just, sustainable, innovative and secure Australian society. Whilst it has a long history, the Society actively looks to the future to address the pressing issues of the day and is a force for good in Australian life.

Barry Jones AC

Science has been central to the exploration and development of Australia, and Enlightenment values, observing, collecting, recording and interpreting data about flora, fauna and geology was a passionate commitment of Cook, Banks, Solander, Spöring, Parkinson, Baudin, Flinders and, later, Darwin and Hooker. Of course, there was a terrible downside: disease, Indigenous dispossession and massacres, and introduction of inappropriate European farming techniques. And we have been very late to recognise the value of Indigenous science: agriculture, diet, navigation, medicine, water management, fire control.

For two hundred years the Royal Society of New South Wales, has played a vital role in research, dissemination and advocacy. In my period as Australia's Minister for Science (1983–90), I was passionate in trying to add new items to the political agenda — not always successfully — climate change, the ozone layer, preserving Antarctica and the Great Barrier Reef, transitioning to a post-carbon economy, the digital economy, emergence of the Third Age, the genetic revolution. Science, and even curiosity, seemed to fall off the political agenda for a decade, and research institutions were under threat.

Now, in my 90th year, what I projected in *Sleepers, Wake!* (1982) seems oddly prescient and I expect our research commitment will improve rapidly.

Always grateful for your support, I salute your achievement and wish you well for the next century (if we make it!).

Kurt Lambeck AC

I congratulate the Royal Society of New South Wales on reaching the distinguished age of 200 years. During these years it has gone through many forms and witnessed much of Australia's history, emerging all the stronger for at a time when knowledge is becoming increasingly fragmented between and within disciplines, yet its implications less well understood by the broad community and policy makers. Today, the RSNSW

through its diverse membership, comprises a major pool of expertise to play an important role in disseminating new knowledge with its consequences, notably at the interfaces of the sciences, arts and humanities, and to provide knowledge-based advice at the State level, and through working with similar national bodies, across state boundaries. I look forward to seeing the Society prosper in the years ahead to the benefit of our nation.

Eugenie Lumbers AM

I am very happy to be joining in this celebration the Royal Society of NSW. For 200 years from its beginnings in 1821 as The Philosophical Society of Australasia, it has promoted knowledge and enquiry into science, philosophy, the humanities and the arts. I am proud of the achievements of the RSNSW.

I believe that new regional branches of the RSNSW like the Hunter Branch can further educate and inform the broader public on how to survive the changing economic decline of the coal industry, embrace the ancient science and culture of our Indigenous communities and enjoy those rewards that come from thinking and doing and in the words of the RSNSW motto '*omnia quaerite*' — question(ing) everything.

Sir Anthony Mason AC

The Bicentennial celebrations are a long history of outstanding achievement by the Society in implementing its vision through knowledge and enquiry.

I trust that the Society's good work will continue well into the future.

George Paxinos AO

Science, which our Society champions, once was called to enrich human life. It rose to the task. It is now called to help human life survive what science enabled — the internal combustion engine, plastics, nuclear weapons, overpopulation. May our Society and science rise to the task again.

Sir Fraser Stoddart FRS

Greetings to the RSNSW on its 200th anniversary from one of its members on his 80th Birthday.

Jill Trewhella

In these challenging times, it is vitally important to have organisations like the Royal Society of NSW dedicated to promoting what is possible to achieve through shared knowledge and understanding. On the occasion of this historic bicentennial year for the Society, I am pleased to send best wishes as we reflect on its proud history and look forward to a continuing positive influence in our community.

Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, pp. 160–163. ISSN 0035-9173/22/020160-04

The Society's NEXUS Exhibition, 2021–2022

John Hardie AM FRSN

RSNSW Librarian

Introduction[1]

The Royal Society celebrated the 200th anniversary of its foundation from July 2021 to June 2022. One of the major events the Society held during this period was its Bicentennial exhibition, NEXUS, designed to highlight the Society's achievements and its contributions to the development of NSW and Australia over the 200-year period. NEXUS was held in the Jean Garling Room of the State Library of NSW (where some of the Society's library collection is housed) from 8 November 2021 to 30 June 2022.

This significant exhibition aimed to highlight and display some of the Society's important archives, most of which are held in the State Library, the obvious choice as the location for the exhibition. Planning for the exhibition determined that it should not only tell the story of the Society's origins and progressive development through its various iterations, but also showcase some of its current and past membership and their influences on intellectual thought and practice nationally and globally. It would be the first time since the 1920s that any of the Society's archives had been on display to the public. It would also provide an opportunity to highlight the "services" of the Society: its library, events, community, awards and publications.

The State Librarian, Dr John Vallance, challenged us to ensure that the exhibition answered his question of "so what?" in relation to the Society. The construct of dividing the exhibition up into the themes of *Origins*, *Ideas*, *Advances* and *Impacts* was developed in direct response to this.

Because of COVID-19, the exhibition was unable to open when originally planned on 26 June 2021; the State Librarian generously provided two extensions to the duration of the exhibition, first to 31 March 2022 and then to 30 June 2022 from its revised starting date of 8 November 2021.

Exhibition content

The title *NEXUS* was chosen for the exhibition as the following two definitions of the word apply equally to the Society:

- a connection or series of connections linking two or more things
- a central or focal point.

A matrix was created to ensure that the various characteristics of the Society were incorporated into the exhibition in some way (e.g. women, youth, literature, art, science, philosophy, branches, high flyers, Distinguished Fellows etc). We associated three major influencers in the history of the Society with each of the four themes of the exhibition: *Origins*, *Ideas*, *Advances* and *Impacts*. These were:

- *Origins*: Alexander Berry (1781–1873), Sir Thomas Brisbane (1773–1860) and Dr Henry Grattan Douglass (1790–1865)

1 This short summary relies on a piece by John Hardie and Wendy Enevoldsen, published in the November/December 2022 issue of the *Bulletin* of the Royal Society.

- *Ideas*: Joseph Maiden (1859–1925), Thomas Keneally (b 1935) and Baron Robert May of Oxford (1936–2020)
- *Advances*: Ida Browne (1900–1976), Sir Ernest Fisk (1886–1965) and Professor Michelle Simmons (b 1967)
- *Impacts*: Professor Elizabeth Blackburn (b 1948), Professor Thomas Maschmeyer (b 1966) and Professor Brian Schmidt (b 1967).

Each of these members had his or her major area of expertise shown below their image on the wall. We used images which showed the context in which each worked. Where we showcased a living person in the exhibition, we provided them with the opportunity to review what we had written about them.

Beside the four themes were displayed short quotes pertinent to the aims of the Society from four of its Distinguished Fellows: Professors Peter Baume, Jill Trewhella, Barry Jones and Kurt Lambeck. A background video was shown in a continuous loop during exhibition opening hours. It contained an introduction to the exhibition by the President and the reflections on the Society by a selection of Past Presidents. The timeline, some past-presidential biographies and some images from NEXUS were repurposed for the Society's Bicentennial gala dinner on 24 June 2022.

Objects

Conservation requirements meant that we were unable to utilise several Society objects, for example, the Society's Letter Book containing hand-written correspondence with the Society from eminent scientists of the 19th and early 20th centuries, and the Society's own copy of the 1821 Kamay commemorative plaque. The National Trust's exhibition "Inquiring Minds," showing in part at the same time as NEXUS, had on display the minute book of the Philosophical Society of Australasia, which meant it was unavailable for NEXUS.

The State Library ensured that the Society's painting of the Rev. W. B. Clarke by Giulio Anivitti (1876), stored in the State Library, was fit for display. It also framed one of its copies of the Kamay commemorative plaque issued by the Philosophical Society of Australasia in 1821 so that it could be displayed in the exhibition. The plaque label was particularly challenging to write, needing to balance the context of the historical event with current perceptions.

The Society was able to provide eight items from its offsite collections for inclusion in the exhibition, one of which, an Australian $20 banknote (now out of circulation) containing an image of Lawrence Hargrave, was kindly lent by an affiliate of the Society. Other items included the President's Chair from Science House, the restoration of which several Past Presidents had generously contributed to, as well as two debossing tools used in the bookbinding of the Society's book collection. All other items were selected from the Society's archives housed in the State Library, as well as a small number kindly lent by the Library itself.

Emeritus Professor Lindsay Botten produced the Past Presidents' video. The original intention was for the video to include a range of material — scholarship winners, forums etc., but we didn't have sufficient time to achieve this. The Society's Librarian made contact with as many Past Presidents as he could locate and organised for them to be filmed in the Jean Garling Room to offer their observations about the Society during

their association with it. He provided three questions to them in advance so that they could prepare for the interview. Only the responses to the first question were included in the final video.

Sponsorships

The Presidents' Chair displayed in the exhibition was restored prior to its relocation to the State Library for the exhibition. This work was generously supported by financial contributions from the following Past Presidents: Ragbir Bhathal, the late David Branagan, the late Edric Chaffer, Trevor Cole, George Gibbons, John Hardie, Donald Hector, Brynn Hibbert, Karina Kelly, Donald Napper, Ian Sloan, and Bruce Warren. A brass plaque recording their contributions is being created for affixing to the chair. A discount was provided by FX framing for the restoration and reframing of the original watercolour of the Society's seal by Archibald Liversidge (1881).

Launch

The exhibition was originally due to be launched at the State Library on Friday 25 June 2021 and to be open to the public the following day. But owing to uncertainties about COVID lockdowns, this was postponed. Indeed, the State government imposed public health restrictions for the Greater Sydney region on that day. This was very disappointing but the Library let the exhibition be moth-balled until it could be opened later in the year. With the easing of restrictions in the latter part of 2021, a new launch occurred on 10 December. The State Librarian was asked to open the exhibition owing to his personal support for it.

Visitors and opening hours

The total number of visitors to the exhibition was 971. This comprised a mixture of Society members and the general public, as well as those visiting as part of special private tours. A Visitors' Book was on display which allowed visitors to comment on the exhibition. The comments were invariably positive.

The Jean Garling Room is not usually open to the public and has been set up primarily as a venue for meetings of the Library Council and the Library Foundation, with a bespoke board table in the centre of the room, and not as an exhibition space. This did not appear to hamper the enjoyment by visitors of the exhibition.

NEXUS was open on Mondays 2–5 PM, Thursdays 3–7 PM and Sundays 2–5 PM. These opening times were in part dictated by the State Library's opening hours.

NEXUS objects into the Society's Archive

A one-off print of the NEXUS title was commissioned to commemorate the bicentenary and to add something tangible that was exhibition-related to the Society's archive. The renovated Presidential Chair, table runner, foyer sign and acrylic labels will also be entered into the Society's archive along with the NEXUS visitors' book, postcard, booklet and launch gift pack example.

Benefits

The exhibition provided these benefits to the Society: increased awareness among the general public of the existence of the Society and how it has benefited NSW; alerting our members to the rich history of the Society and its contributions; and creating a deeper,

more productive relationship with the State Library of NSW.

Conclusion

The NEXUS exhibition achieved its aims of appropriately celebrating the 200 years of the Society and its antecedents, bringing the Society to the attention of the general public in a novel way, generating a greater understanding among members of the richness of their Society and utilising the Society's valuable archives for its practical benefit.

Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, pp. 164–167. ISSN 0035-9173/22/020164-04

Bicentennial celebrations
The Admiralty House vice-regal reception

His Excellency General The Honourable David Hurley AC DSC (Retd)

Susan M Pond AM FRSN FTSE FAHMS (President, RSNSW)

Her Excellency, Mrs Linda Hurley

Originally scheduled to be part of our celebrations in 2021, this reception was delayed not only by the pandemic but also by competing demands during 2022 on their Excellencies' time. These included but were not limited to the Platinum Jubilee celebrations of Elizabeth II's accession, the ongoing torrential flooding throughout the year in the Eastern States, the Australian Federal Election, and the death of Queen Elizabeth II. Their Excellencies, His Excellency General the Honourable David Hurley AC DSC (rtd), and Her Excellency Mrs Linda Hurley graciously made time available for a small reception for 35 people at Admiralty House, Kirribilli, on 7 November 2022.

The Honourable David Hurley

Good evening, all. Linda and I are delighted to welcome you to Admiralty House for what is a celebratory occasion: the 200th anniversary of the Royal Society of New South Wales. I temper my excitement for your celebration ever so slightly, because two months ago we lost our Queen. It was Her Majesty's great-grandmother, Queen Victoria, who granted Royal Assent to the Society in 1866. So, in celebrating the Society's bicentenary, we also reflect on Queen Elizabeth II's lifetime of service.

As this audience knows, Linda's and my association with the Society goes back many years to my Governor of New South Wales days. As a former Patron of the Society, I thoroughly enjoyed the many occasions in which we gathered to consider some of the big issues of the day. One of those occasions was nearly four years ago to the day, in a speech I delivered to the 2018 Royal Society of New South Wales and Four Learned Academies Forum entitled, "Towards a prosperous yet sustainable Australia — what now for the Lucky Country?" Here is an excerpt from that speech: "Travel through the drought-stricken communities of New South Wales at the present time — they're a bit down. But they are enormously resilient. They look out for each other; they create opportunities; they re-invent their communities."[1]

I have been reflecting on those comments, particularly given that many of those same communities have recently been impacted by flooding. What comes to mind? That our response to current challenges — that ability to stare adversity down — has not diminished one iota in the ensuing three years. How do I know that? Because of the many visits Linda and I have made to disaster-affected communities and the people we've met, including today in Moree.

We are, at our core, a good and strong people. We see it in our response to the floods. We saw it our response to the 2019–20 fires and other natural disasters.

1 See https://royalsoc.org.au/images/pdf/journal/152-1-Hurley.pdf

Communities on their knees, but not out. People who are resourceful, gritty, innovative, determined, supportive and compassionate — a "richness of spirit" is how I like to describe those characteristics all wrapped up. Those characteristics are not confined to communities impacted by natural disasters. They are on show in myriad ways around our country every day of the year. Good people, good organisations — improving the lives of those around them. I include the Royal Society of New South Wales in that special group.

The Society and other members of that special group epitomise the characteristics of our late Queen. History will remember few like Queen Elizabeth II. We have witnessed — and benefited from — her remarkable life. Noting all that changed during the Queen's 70-year reign and all that will change in Australia in the next 70 years, there is a timeless quality that we can draw from Her Majesty. For what did not change were the values and characteristics that Her Majesty lived by from the moment she acceded to the throne as a young adult, becoming monarch with scant preparation but with a deep reservoir of strength and faith. They were a constant. Her dutiful service wasn't an act; it was who she was.

Throughout her reign, she consistently demonstrated tireless and selfless service, devotion to duty and a compassion for others. Her Majesty epitomised servant leadership and, particularly in this age of extreme individualism, set an example of living and serving for something greater than herself. That is her enduring gift to us all. Again, it is a delight for Linda and me to share in your bicentenary celebrations. It's impressive — 200 years is a remarkable achievement and a credit to all members of the Society, past and present. We look forward to spending some time with you and celebrating.

The President's response

Thank you, Your Excellency, for your uplifting remarks. I extend my own welcome to Fellows, Members and Friends of the Society. We stand here in this beautiful spot in Kirribilli, thanks to their Excellencies, His Excellency General the Honourable David Hurley AC DSC (Retd) Governor-General of the Commonwealth of Australia and Mrs Linda Hurley. As you have just heard, they know the Society well. I mentioned this beautiful spot, Kirribilli, because it is also where I am proud to reside. It is named after the First People's name *kiarabilli*, which means "good fishing spot." It remains so today. We acknowledge the traditional first peoples of this land. They are the Cammeraygal people of the Eora Nation. We pay our respect to their leaders — past, present, and emerging.

Emerging is an important word tonight, in the context of this welcome to country and emerging leaders and for the Royal Society of New South Wales. As His Excellency noted, the Society is completing its two-hundred-year milestone celebrations. Notable amongst these celebrations have been the Society's exhibition, NEXUS, which was on display in the State Library of NSW from November 2021 to June 2022, the Garden Party hosted by our current Patron, Her Excellency, the Honourable Margaret Beazley AC KC at Government House in March this year, our Gala Dinner in the Great Hall of the University of Sydney on 24 June 2022, and of course, tonight's reception.

Perhaps we could say that one silver lining of the COVID-19 pandemic cloud is that we were forced to delay the celebrations

planned for 2021 and then stagger them over many months once public health restrictions were lifted. The additional months gave the Society time to review and deepen its understanding of its 200-year-old heritage, archives, and its impact, and bring them to light in various publications and forums, and, more importantly, in people's minds. We are all the richer for that, especially because of the opportunity to acknowledge that we cannot change history, but we can ensure that we are not perpetuating legacies that these days we find to be abhorrent.

This reception was planned originally to be part of our bicentennial celebrations in May 2021. Another silver lining of the pandemic is that this delayed reception affords us the opportunity to inaugurate the Society's third century. As you read in your invitation to attend tonight, the Society looks forward during the next century to shaping and delivering Australia's future, the future that we all want. And what is that future?

The past two and a half years have been extraordinary. The unnerving combination of a global pandemic compounded by energy scarcity, rapid inflation, and geopolitical tensions boiling over leave us wondering what certainties are left. But even with so many uncertainties, there are good reasons to believe that the future can be bright. It must be bright. We must make it so. Many issues can, at least in part, be addressed with current technologies if we are able to prioritise and deploy them systematically and focus our efforts. We saw this play out in the eye of the global hurricane presented to us by the pandemic. It forced us to prioritise and accelerate quick wins in healthcare, to name but one of many sectors.

The pandemic sparked so many innovations. I mention only a few — telehealth, virtual hospitals, drones delivering medical supplies, cloud-based monitoring of home ventilation devices, McMonty personal ventilation hoods,[2] and, of course, invention and deployment of rapid diagnostic tests and delivery of new vaccines in record time. But delivering the future we all want requires more than technology.

The future we want will not happen without intelligent, concerted effort, without fostering knowledge and creativity as important drivers of social and economic wellbeing, without bringing the sciences and humanities together to set the course through the many unresolved questions and steer toward better outcomes. These are the ambitions of the Royal Society of New South Wales as it seeks to improve the lives of many. These are the ambitions embodied in the Society's ideals: commitment to advancing the best interests of society; a questioning spirit; diverse and inclusive engagement; boldness and innovation; and good governance. None of these ambitions will be achieved without the work of the Society's volunteer Council and Committees, the input and contributions by all its members, and generous support by sponsors and donors. I thank you all for being here tonight. I look forward to your continued engagement with the Royal Society of New South Wales and with its ambitions as it enters its third century.

2 See https://innovationaccelerationprogram.com.au/case-studies/mcmonty-hood/

Her Excellency, Mrs Linda Hurley

Well known for wanting the world to sing, Her Excellency performed the song she wrote for the Society, then led guests in singing the chorus of "You are my Sunshine" three times to ensure that everyone joined in.

Royal Society of NSW founded in Sydney 1821
Philosophical Society Australasia how it begun
Science, Art, Literature, Philosophy, knowledge
Advanced Studies, Investigations member-ship you see

The first Scientific Society in British Colony NSW
A special group of influential men like minded had their say
Sir Thomas Brisbane Governor the first President
Royal Society of NSW Queen Victoria granted Royal Assent

The Society has done much work to foster local Research
Science, Meetings, Symposia, Publications, Fabulous work
The Society encourages studies in Philosophy Literature Art
Awarding prizes and medals achievements in research a part

Liaison with similar bodies maintain a library too
Open to all people their aim to bring knowledge out to you
Committed to advancing the best interests of Society
A questioning spirit boldness and innovation you can see.

Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, pp. 168–181. ISSN 0035-9173/22/020168-14

Silicon solar cells to power the future

2022 Millennium Technology Prize Lecture

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Introduction

It's a great honour to have been announced as the winner of the 2022 Millennium Technology Prize for my work on accelerating the development and uptake of silicon solar cells. In my lecture, I'd like to give an overview of our work and outline how such work has now positioned solar to play a major role in climate change mitigation. The images on my cover slide (Fig. 1) show the iconic Sydney Opera House, also the building where my research labs are located at the University of New South Wales (now UNSW Sydney), solar powered, of course, and our Solar Industrial Research Facility where we undertake technology transfer to industry.[1]

Figure 1: Sydney Opera House; UNSW Tyree Energy Technology Building (TETB); UNSW Solar Industrial Research Facility (SIRF).

My talk is divided into three sections. First, I'll talk about technology, then costs and, finally, recent market drivers that are sustaining very rapid present expansion of solar uptake. So, hopefully, there is something interesting in my talk for everyone.

Technology

Operation

First, technology. Figure 2(a) shows the cell operating principles — cells are very much 20th-century devices, essentially quantum converters, relying on the 20th-century developments in quantum mechanics to understand their operation. Photons in sunlight with sufficient energy enter the cell, giving up their energy by exciting electrons from silicon atomic bonds, creating electrons in excited states and leaving vacancies or holes in the bonds, that act as positive charge carriers. Without any other features, the excited electrons would just relax back to their initial states and nothing useful would happen. What is required is an electronic asymmetry to give a directional flow to the electrons and holes. This is where what is called a "positive-negative junction" or "p-n junction" comes into play, with such junctions one of the most important building blocks in microelectronics.

1 In October 2022, Martin Green won the Millennium Technology Prize, Finland's top technology award. This is his acceptance speech. Presentation of actual lecture can be found at https://millenniumprize.org/events/award-ceremony-2022/. Lecture was extemporised so text is the intended lecture, also including some information additional to what the allocated presentation time allowed and excluding some of the visual material actually presented.

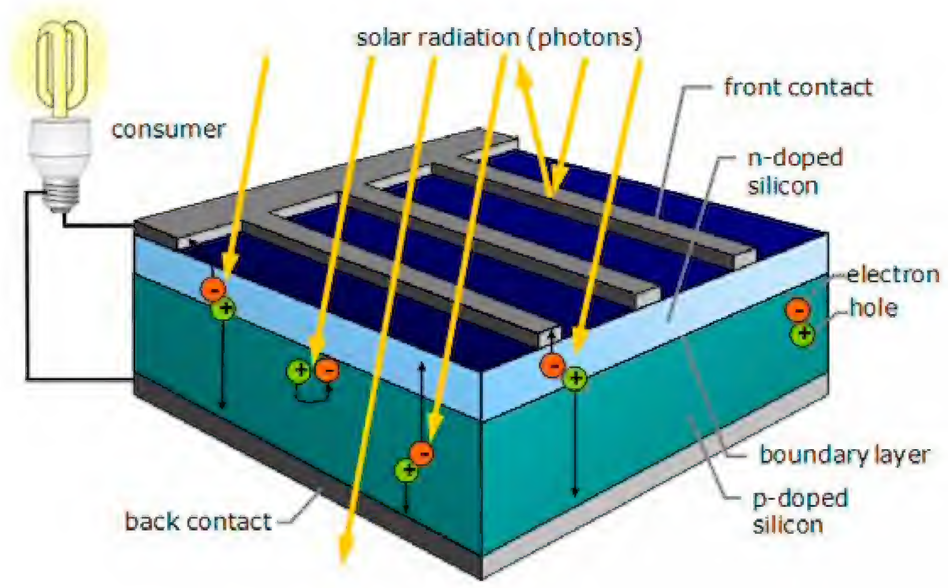

Figure 2(a) Operating principles of a solar cell (Quaschning, 2019).

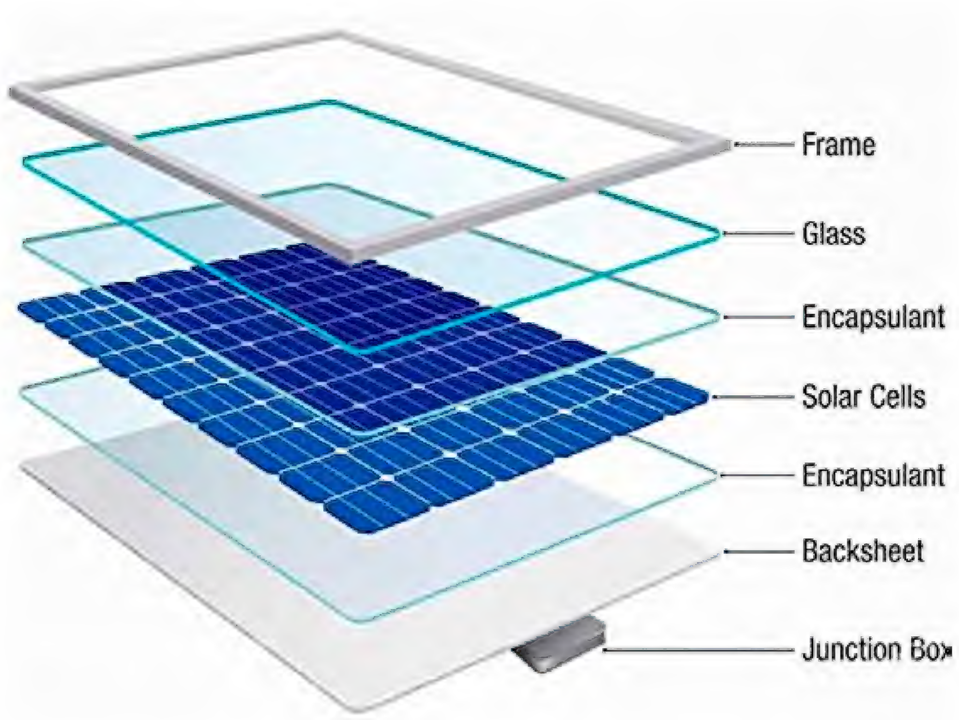

Figure 2(b) Solar cell encapsulation into a solar module (DuPont, 2016).

This junction was actually discovered and named when the first silicon solar cell was accidentally made in the early 1940s. Serendipitously, a piece of relatively pure silicon was prepared that generated a voltage when illuminated by a torch, with a clear junction between the region that showed a positive voltage and the region showing a more negative voltage. Working out what caused this ultimately led to the microelectronics revolution.

It was found that the different properties were due to small quantities of trace impurities in the silicon. Silicon comes from Group IV of the old periodic table. Elements from Group V have more electrons available, making it easy for electrons to move through silicon when such impurities are present, forming "negative" or "n-type" regions. Elements from Group III have fewer electrons, or more holes, so holes can easily move through silicon when these impurities are present, forming the "p-type" regions. So, in a cell as in Fig. 2(a), with the n-type region uppermost, electrons can readily flow to the top and holes to the back.

Without any electrical connection between the top and the bottom contacts to the cell under illuminated by light, you would measure a voltage difference between the top and bottom called the "open-circuit voltage," something that I will talk about later. But, if you connect an electrical circuit between the top and back, such as the light bulb shown, electrons will flow through the circuit around to the back of the cell, where they will meet up with holes and complete the cycle.

There are no moving parts involved or inherent wear-out mechanisms, so the cells are very reliable. The cells are now made very thin and can be mechanically fragile, so are packaged into a solar module with a strengthened glass cover sheet and aluminium frame, providing mechanical support, with a tough back cover laminated to the module rear providing electrical and chemical protection. Modules are very reliable, with manufacturers now warranting them for between 25 to 40 years.

First efficient cells

The first efficient silicon solar cells were made in 1953. Perhaps very appropriately, given the important role solar cells now seem likely to play in our energy future, this made front-page news in the *New York Times* in April 1954 — "Vast power of the sun is tapped by battery using sand ingredient."

Figure 3(a) Vanguard 1 satellite launched in March 1958 (Image: Wikimedia Commons).

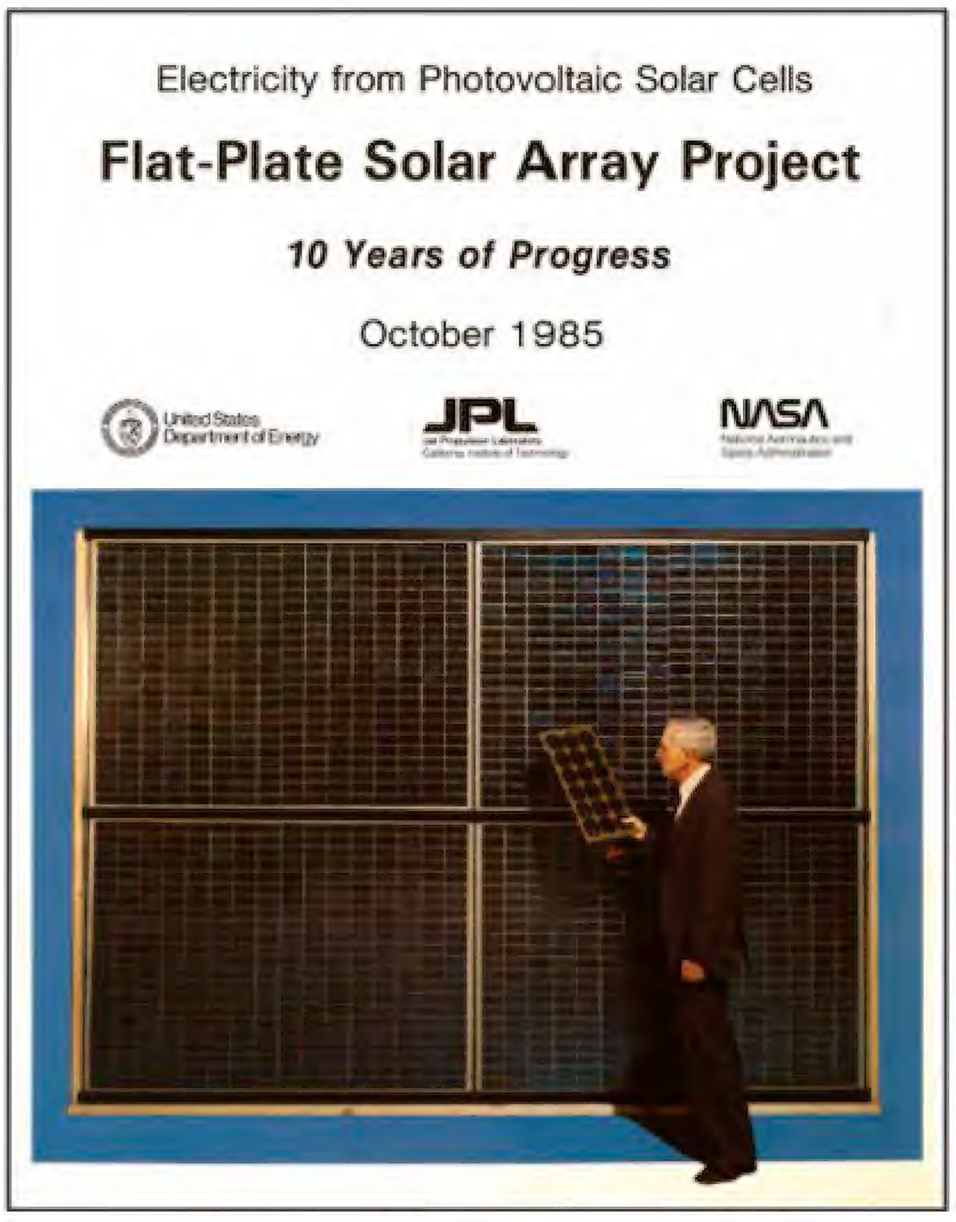

Figure 3(b) Tenth-year progress report on the Flat-Plate Solar Array Project started in January 1975 (Christensen, 1985).

There was excitement about possible uses, such as providing energy for a family as shown in the drawings accompanying the press release, but the cells were then far too expensive for any such use to be feasible.

Fortunately, the cells almost immediately found an application where cost was not a big issue: in space. Proponents were successful in having cells flown on the second US satellite, Vanguard 1, in 1958. These worked very well, too well in fact, since there was no "off-switch" and the signals they powered clogged up airwaves for the next six years. However, this showed the cells were ideal for powering communication satellites, pioneered by Telstar in 1962. Bell Labs were given the job of developing reliable solar cells for this mission, developing an improved design that became the workhorse for the industry, known as the conventional space cell (Smith et al., 1963).

Project Independence

Things might have stopped there, except for the 1973 Arab-Israeli war that sparked an oil crisis, in the US in particular. President Nixon launched "Project Independence" in late 1973 to wean the US from foreign oil. Crucially for subsequent developments, solar was selected as a candidate for doing this, leading to the "Flat-Plate Solar Array Project" that ran for 10 years from 1975 (Christensen, 1985), specifically aimed at substantially reducing the cost of solar cells. Massive progress was made such as in the area of module packaging, which evolved dramatically over this period through a series of "block purchases" targeting ongoing improvements. The designs resulting from this period remain in force right up to the present.

The program also consolidated then recent improvements in cell design and fabrication. Space cell researchers found they could etch the cell surface to produce the tiny pyramids shown in Fig. 4(a), greatly reducing reflection and improving cell performance substantially. At about the same time, a very simple way of making the contacts to the cell was suggested by screen-printing the patterned metal contacts as a paste, much

like printing patterns onto a T-shirt, then heating to high temperatures to solidify. At the rear, an aluminium paste was used that introduced p-type aluminium dopants into the silicon at the high temperatures involved, further improving cell performance. The "aluminium back surface field" cell was a very advanced design for the era and was so successful that it remained the dominant commercial technology for the next 40 years.

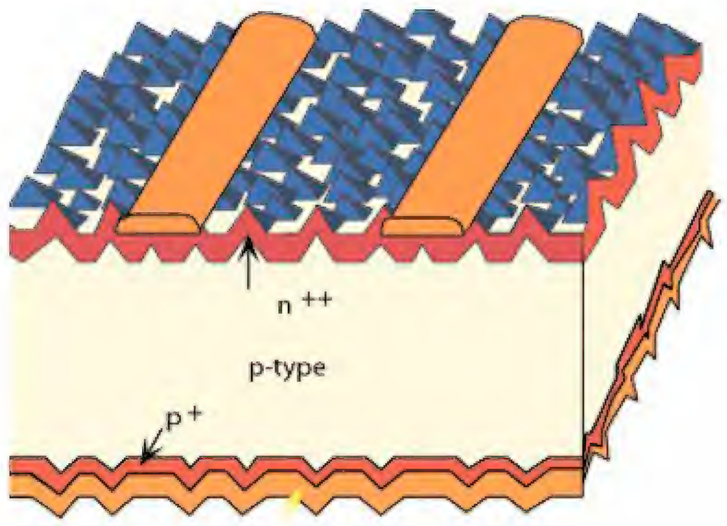

Figure 4(a) The "aluminium back surface field" (Al-BSF) solar cell that was a combination of the pyramidally textured "black cell" developed by COMSAT Laboratories in 1974 (Alison et al., 1974) with "screen-printed" contacts (Ralph,1975). The "back surface field" refers to the heavily doped p+ region at the cell rear that helps prevent electrons from reaching the rear contact.

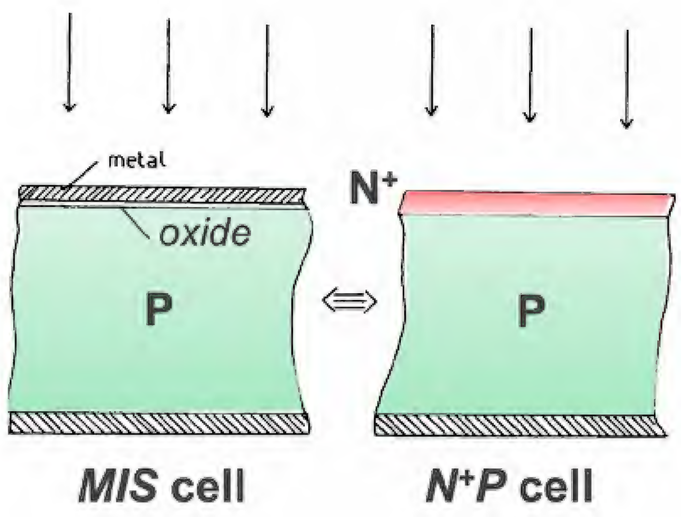

Figure 4(b) The metal-oxide-semiconductor (left) studied in the author's thesis when the normally insulating oxide layer was sufficiently thin to allow quantum mechanical tunnelling between the metal and semiconductor. With appropriate choice of the metal, this was shown to give identical properties to an ideal p-n junction diode (right).

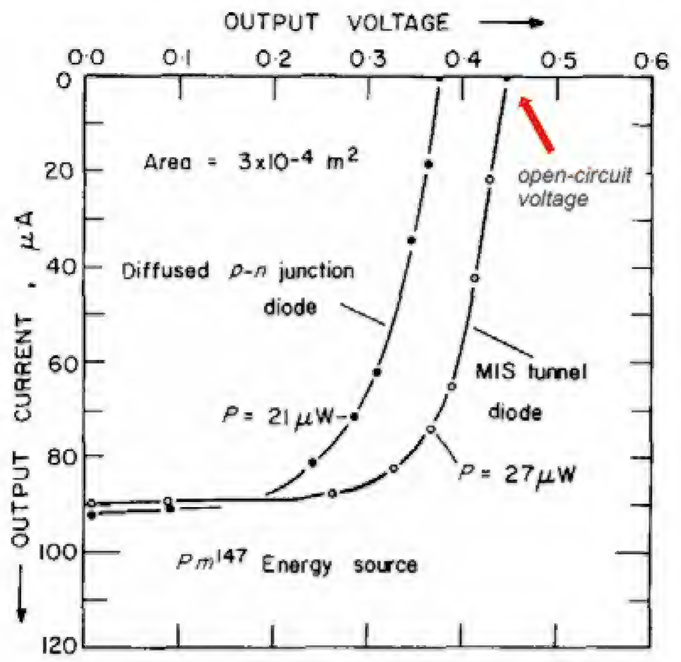

Figure 4(c) The author's cells outperformed the best p-n junction cells being made for a McMaster University project to develop long-life pacemaker batteries based on the betavoltaic effect, using high-energy electrons from a radioisotope instead of photons as the excitation. Notable is the very high open-circuit voltage demonstrated (over 650mV at solar intensities!) (Shewchun et al., 1972).

Tunneling contacts

Meanwhile, I was working on my PhD in Canada at McMaster University, where I had won a scholarship from Australia. My research (Green, 1974) involved a common microelectronic structure, the metal-oxide-semiconductor structure shown in Fig. 4(b), but I investigated it when the normally thick insulating oxide was thin enough to allow electrons to pass through it by quantum-mechanical tunnelling. One major result I found was that, when designed correctly, the device could replicate the properties of an ideal p-n junction diode. This made it of interest for solar cells although McMaster was better set up for nuclear work, having its own reactor. My thesis supervisor had a project to develop a pacemaker battery using electrons from a radioisotope, rather than photons, to illuminate a p-n junction. My devices worked much better than the p-n junctions being developed by other students for the project. Particularly notable

is the very high open-circuit voltage shown in Fig. 4(c), a reliable measure of p-n junction quality. This was my first successful experimental foray into energy conversion (Shewchun et al., 1972).

Early years at UNSW

On returning to Australia, I started the solar group at UNSW in late 1974. By 1976 my first PhD student, Bruce Godfrey, and I were getting good results in applying my thesis structure to solar energy conversion, with us both shown at work in Fig. 5(a). Fortunately for us, NASA had launched a program to improve silicon cell efficiency by increasing the open-circuit voltage and, despite our then very modest facilities apparent in the figure, we were able to beat all NASA subcontractors in terms of the voltages demonstrated, as shown in Fig. 5(b). This brought our work to international attention, with our small team receiving an invitation to present a plenary paper at the 14th IEEE PV Specialists Conference in San Diego (Green et al., 1980), then by far the most important international conference series in photovoltaics. This international endorsement of our work helped me raise the funding needed to put together the larger team and facilities to develop the other cell features required for an assault upon the cell efficiency record, particularly highly conductive, fine linewidth plated metallisation fingers and double layer antireflection coatings. The late Erik Keller, an experienced engineer supported by one of my grants, did a superb job in both areas.

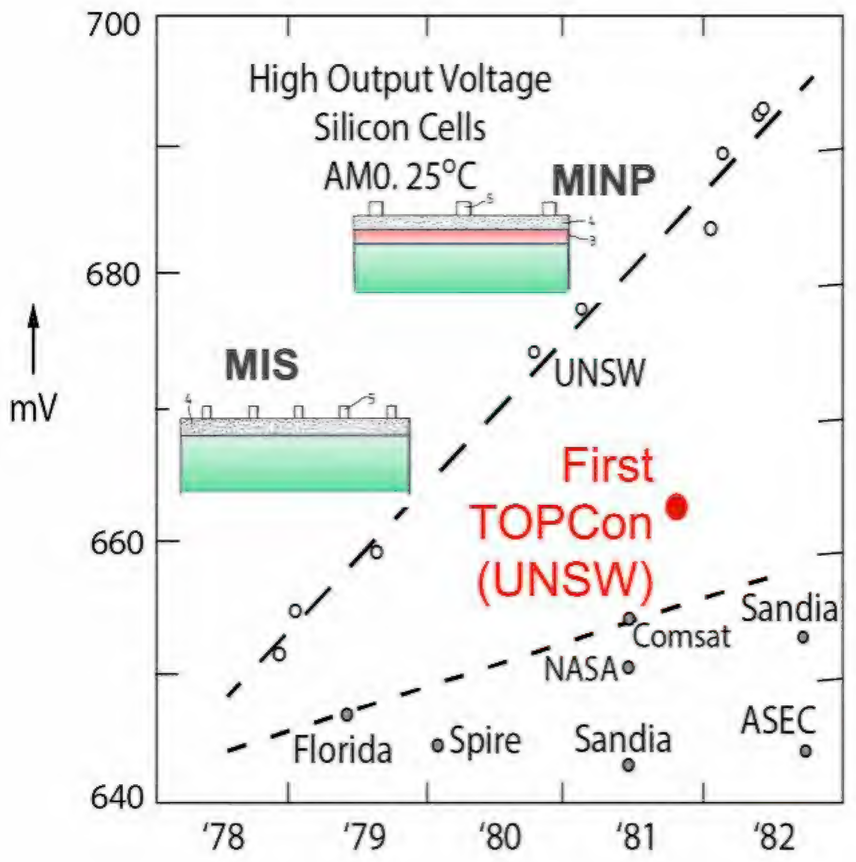

Figure 5(b) Highest reported silicon cell open-circuit voltage over the 1978–1982 period, showing how UNSW outperformed NASA and NASA subcontractors.

Figure 5(a) Martin Green (left) and Bruce Godfrey getting last-minute results for the 12th IEEE PV Specialists Conference in Baton Rouge in 1976 (Green et al., 1976).

Meanwhile, our voltage lead had been further improved when my 2nd PhD student, Andrew Blakers, and I serendipitously discovered that combining our tunnelling structures with a lightly doped p-n junction gave better results than tunnelling alone. I coined the acronym "MINP cell" (metal-insulator-NP junction cell) for the resulting devices (Green et al., 1981).

Since the metals being used reacted with the oxide at high temperatures, we realised these structures would not be suitable for use with the screen-printing process used in manufacturing. To demonstrate compatibility of the tunnelling approach, we

fabricated devices (Fig. 6) with the metal replaced by heavily doped polycrystalline silicon that acts nearly like a metal but does not react with its underlying oxide even at high temperatures. This structure successfully demonstrated record voltages, outside our group at least, and is now being used commercially in "TOPCon" cells.

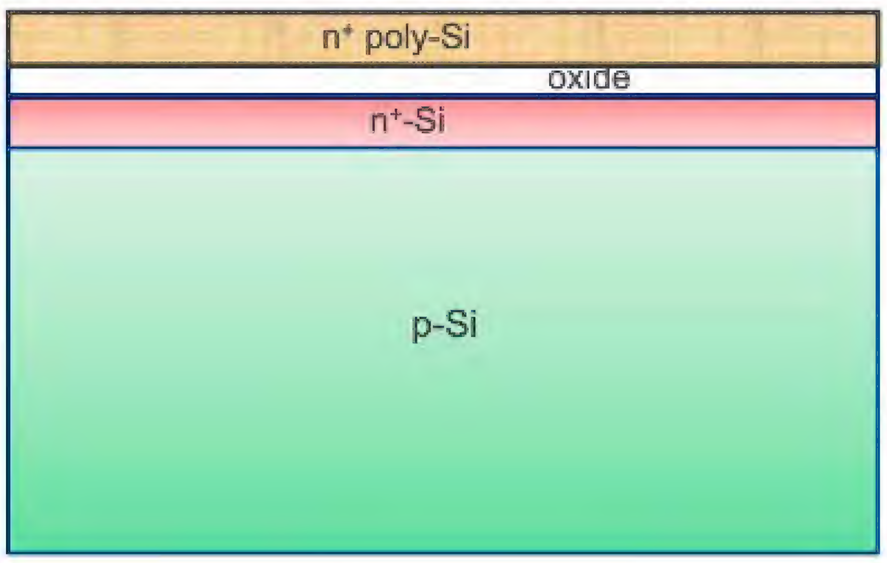

Figure 6: MINP cell fabricated in 1981 with the metal layer replaced by a thin heavily doped polycrystalline silicon layer (Green and Blakers, 1983; Green, 1987; Green, 1995). This approach has reportedly since been used commercially by SunPower and Tetrasun and now, more widely, in "TOPCon" cells.

With our large voltage lead, we were well-placed to improve cell conversion efficiency. Success came in September 1983 with the tunnelling structure shown in the insert of Fig. 7(a) producing a cell confirmed as 18.7% efficient (18.1% by present standards), the first record for a group outside the US (Green et al., 1984a). The photo shows the team involved, with my second and third PhD students, Andrew Blakers and Stuart Wenham, behind me as well as Jiqun Shi, a visiting scholar from China, and grant-supported engineers, Erik Keller and Ted Szpitalak at the front. This was the first of 18 world records we set over the next 30-years, improving certified cell performance by over 50% over this period as shown in Fig. 7(b) (Green, 2009).

Figure 7(a) Team producing the first 18% efficient silicon solar cell in 1983. Left to right: Erik Keller, Jiqun Shi, Martin Green, Stuart Wenham, Andrew Blakers and Ted Szpitalak. The insert shows the MINP cell structure used.

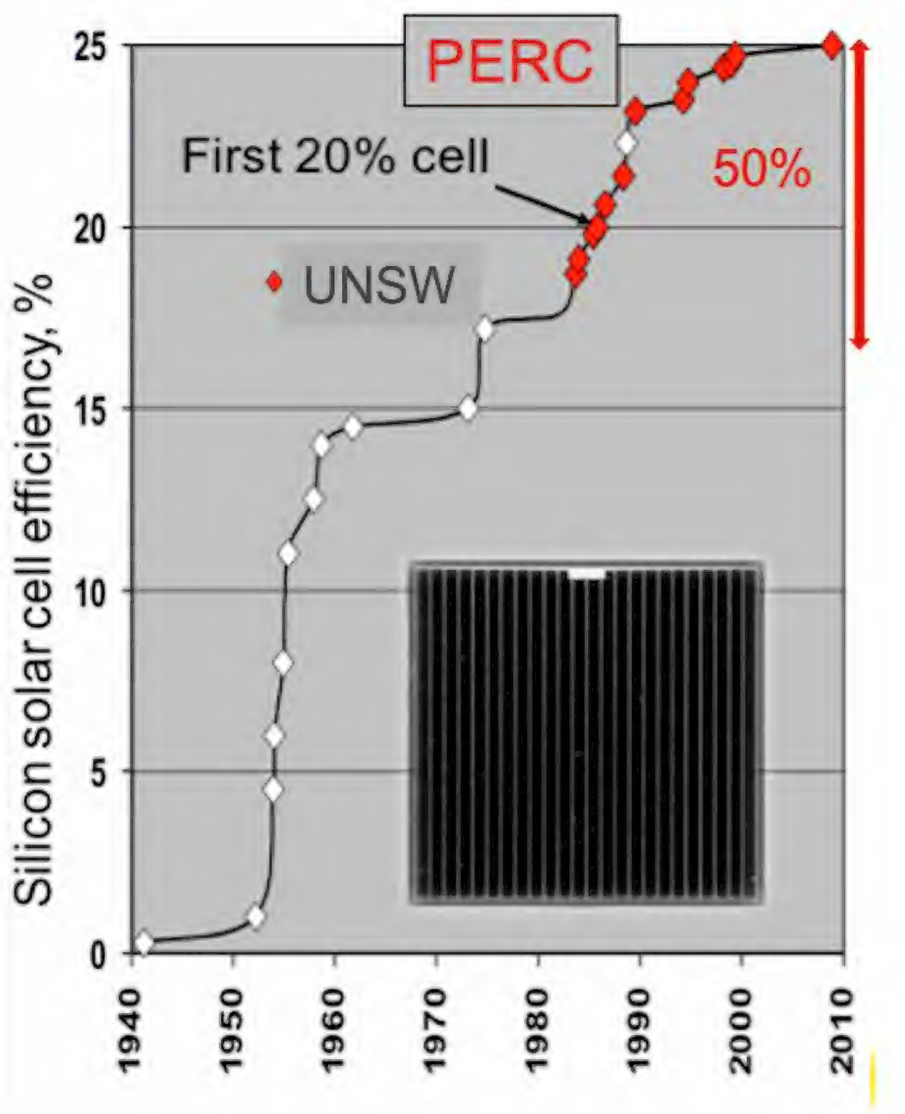

Figure 7(b) History of silicon solar cell efficiency evolution showing UNSW impact over a 30-year period, improving the highest confirmed efficiency by more than 50% in relative terms. Highlights include producing the first 20% cell in 2005 and the first record PERC cell in 1989, eventually achieving 25% efficiency. The insert shows the physical appearance of the 2cm x 2cm cell setting the team's first record.

Meanwhile, I had been studying what efficiency we might ultimately expect from silicon and what cell design features would be required. In the same journal issue where our first record was published, I also published the results of this study (Green, 1984b). Key findings were that silicon was capable of energy conversion efficiency closer to 30% than the 20% value previously thought a practical limit, with 25% estimated as a feasible target. My work also showed that we needed to eliminate the "aluminium back surface field" that was such an important part of commercial cell design to reach such efficiencies.

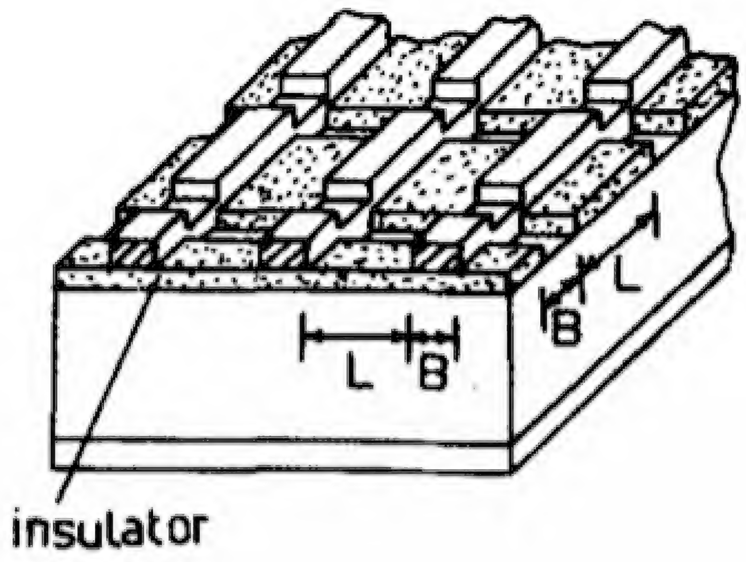

Figure 8(a) Low area contacting approach used to verify the high voltage potential of PESC solar cells (Green, 1975).

When Stuart Wenham and I were giving the record MINP cells their final anneal, we found that higher annealing temperatures than we expected gave best results. We postulated that the metal may have been penetrating the oxide in small area filaments. I had earlier suggested such small area contacts as a way of reducing the detrimental effects of metal contact recombination (Green, 1975). So Andrew tested out a structure I had suggested in my earlier work, shown in Fig. 8(a), and it worked well, giving us a second way of getting high voltage with the advantage that it simplified cell processing. This gave us our second world record in December 1983 with a cell confirmed as 19.1% efficient (18.4% by present standards) (Green et al., 1984a).

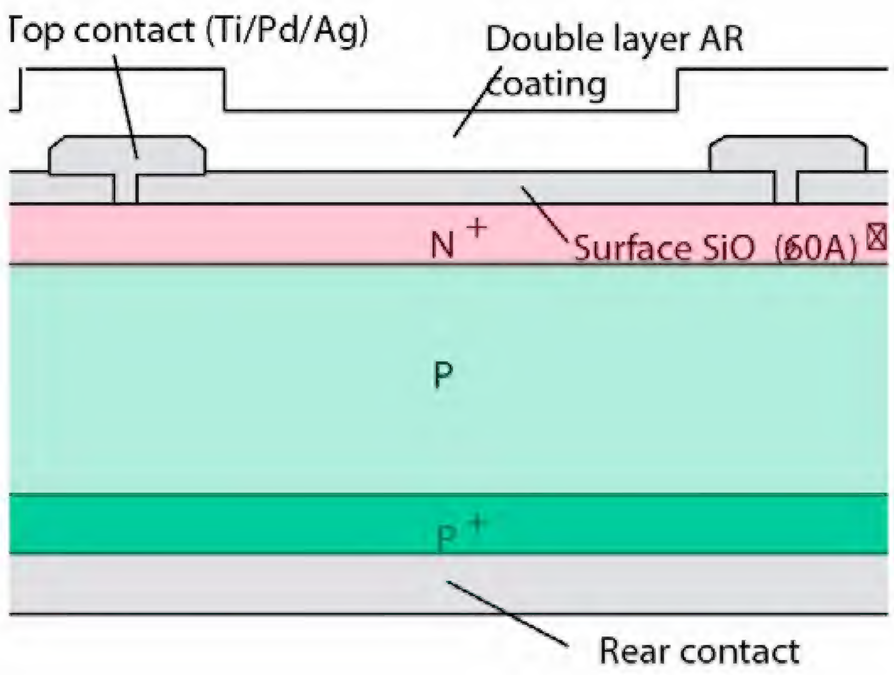

Figure 8(b) PESC cell confirmed as 19.1% efficient in December 1983 (Green et al., 1984a).

I named this the "passivated emitter solar cell" or PESC cell shown in Fig. 8 (b), where emitter refers to the top of the cell. Based on this development, my theoretical paper and earlier experimental work I had supervised on increasing cell rear reflection, I drew my first diagram of a cell design improving upon the "aluminium back surface field" towards the end of 1983, including the drawing in Fig. 8(c) in two reports released in early 1984. I quite naturally named this the "passivated emitter and rear cell" or PERC cell, since this development fixed up both top and rear of the cell.

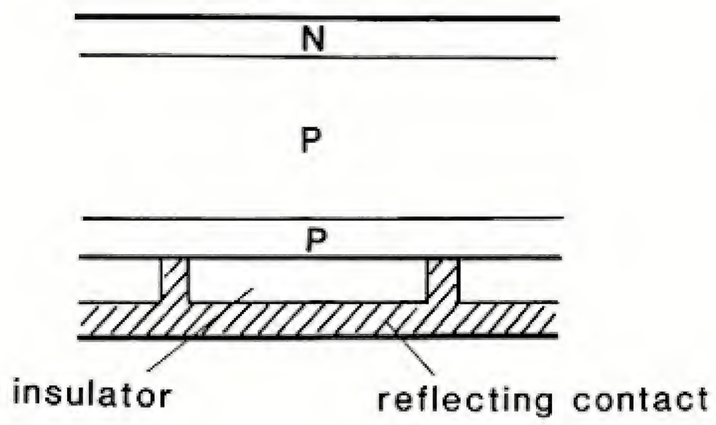

Figure 8(c) First drawing of PERC solar cell emphasising rear contact design (Green, 1984b; Green et al., 1984c).

Another idea mentioned in the two reports, texturing the top surface, was more readily implemented. By including this, we achieved the landmark 20% efficiency in 1985, long regarded as the "four-minute mile" of photovoltaics. The very happy team contributing to this achievement is shown in the first photo in Fig. 9 with myself surrounded by six PhD students and two grant-supported engineers. The observant might detect a certain gender imbalance. This was soon partly rectified by the addition of the late Adele Milne, who completed the first-ever PERC thesis worldwide, and Aihua Wang and Ximing Dai, who made important contributions to our lab and then to the development of the solar industry, being founders and Chief Technical Officers (CTOs) of CSUN and JA Solar, two of the companies early into manufacturing in China.

Figure 9: Team producing the first 20% efficient silicon cell in 1985 together with subsequent team members contributing to both cell efficiency improvement and to the solar industry's transformation.

The emphasis was then placed on implementing PERC. Using a process developed by Andrew Blakers, Jianhua Zhao made the first efficient PERC in September 1988 with 21.8% efficiency confirmed (21.2% by present standards). This would have been a world record except that Stanford University reported a 22.3% efficient cell at about the same time using a sophisticated approach with both contacts on the rear (22.5% by present standards!). This put pressure on us to regain our record. Andrew got closer with 22.2% confirmed in February 1989 (21.6% by present standards), when he left for Germany to take up a Humboldt Fellowship. Jianhua then became our processing leader with Aihua Wang fabricating a certified 22.8% cell by adding two extra high-efficiency features, regaining our record (although this result was later recalibrated to 22.2%, a lower value than Stanford's!). I quickly wrote a paper reporting this result giving the honour of first authorship to Andrew, despite his absence, to recognise his 10 years of lab contributions (Blakers et al., 1989). The structure reported retained the simplified design suggested by Andrew but, with Jianhua now our processing leader, the originally conceived rear doping was soon implemented with efficiency steadily increasing to our 25% target, confirmed in 2008 (Green, 2009). Stanford's 6-month or so interruption to our run of efficiency records was the only one over 31 years.

Since 2014, three other cell technologies have exceeded the 25% mark (Fig. 10). The second one in Fig. 10(b) labelled TOPCon reverts to use of the tunnelling polysilicon contacts our team demonstrated back in 1981. The third, the heterojunction (HJT) cell, is based on a junction between thin layers of silicon in amorphous form and the normal crystalline material. Citing our earlier work, it was initially found that inserting a thin oxide layer between the thin amorphous

layer and the crystalline material improved performance (Morikawa et al., 1990) but a thin layer of undoped amorphous silicon was then found to do an even better job (Taguchi et al., 1990). The fourth structure, the "interdigitated back contact" (IBC) cell is the oldest of all the structures (Lammert and Schwartz, 1977), but is also linked to our early work since now using either HJT, TOPCon or mixed TOPCon/PERC approaches for the back contacts.

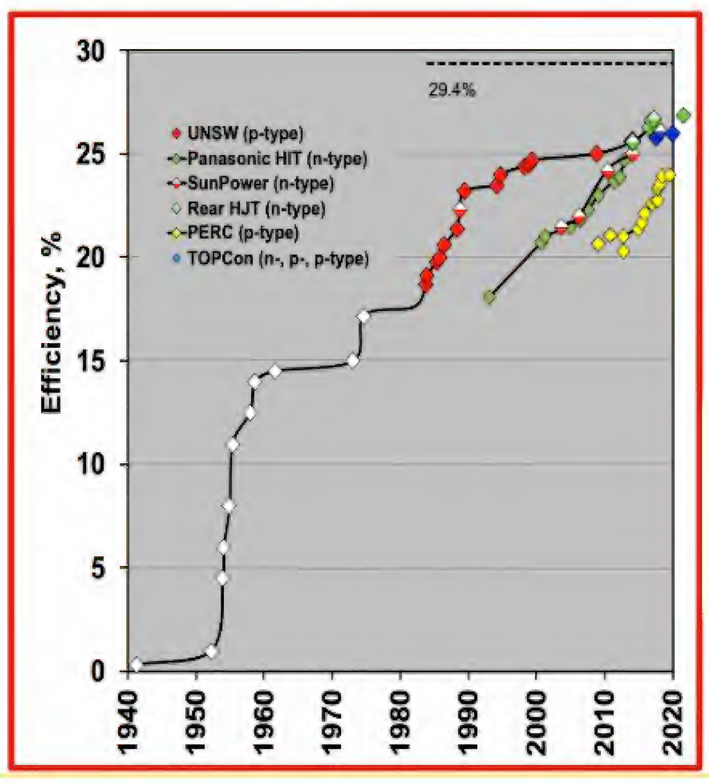

Figure 10(a) Recent developments in silicon solar cell efficiency.

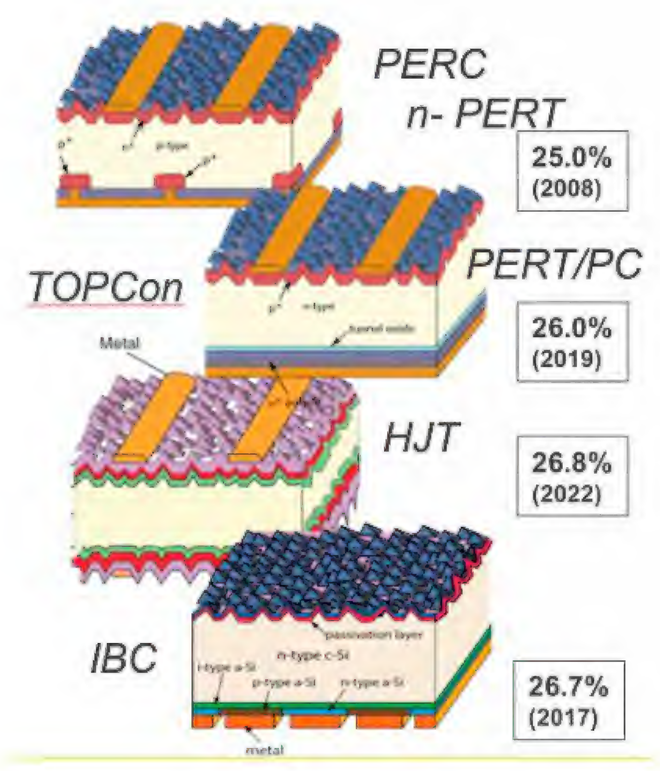

Figure 10(b) PERC cell diagram together with those of the other three silicon cell structures that have exceeded 25% cell efficiency since 2014. The present record efficiency is 26.8%, obtained in October 2022.

However, when it comes to production, PERC now completely dominates. Figure 11 shows market share, dominated for 40 years by the "back surface field" technology, the blue and maroon regions, with the first cell demonstrated in 1975. PERC, the brown and yellow regions, began challenging after 2015, now completely dominating the market with over 90% market share in 2021.

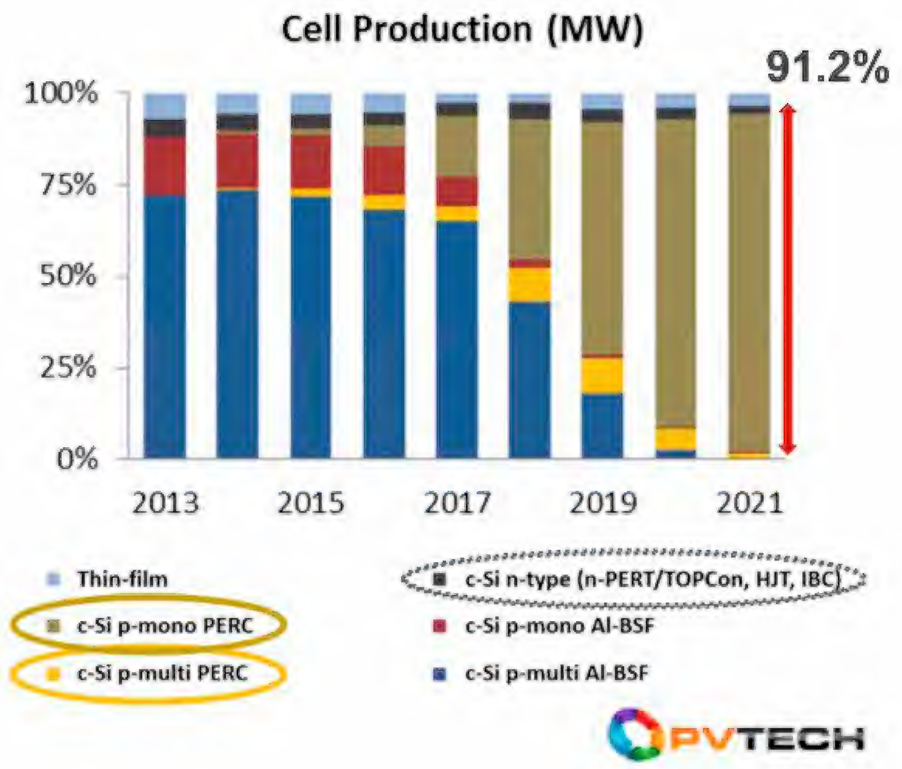

Figure 11: Share of the photovoltaic module market by different technologies (Image: PV Tech, 2022). Until 2015, the Al-BSF technology shown in Fig. 4(a) dominated the market but was then quickly displaced by PERC technology, with 91.2% share of the silicon market in 2021 (CPIA, 2022). The other high efficiency technologies presently share the small black regions of the chart, but are expected to become more important in the future.

Another contribution to technological uptake has been graduates from our lab. I have now supervised over 120 PhD students, but these efforts were complemented in 2000 when, anticipating the upcoming explosion of the industry, we introduced the world's first undergraduate degree program in photovoltaic engineering. With both local and international students enrolled, the program has supported the growing

demand for trained engineers, particularly in Australia and China (Fig. 12).

Figure 12: The 2010 intake into the School of Photovoltaic and Renewable Engineering, the first in the world to offer an undergraduate degree in Photovoltaic Engineering. In the foreground are the inaugural and third (and current) Heads of School, Richard Corkish (left) and Alistair Sproul, both former PhD students of the author.

Costs

Historical cost decrease

That brings us to costs. Figure 13 shows a compilation of photovoltaic module costs and prices over 4 decades (Kavlak et al., 2018). Straight lines on this semilogarithmic plot represent exponential reductions, with prices reducing consistently at a compounded rate of 7%/year from 1980 to 2005. Then something happened, with price reductions markedly accelerating. Based on a "business as usual" projection with 7%/year price reduction, module prices would have been expected to reach US $1/Watt in 2020. Instead, they were 5–6 times lower, reaching prices as low as US 15 cents/Watt.

The person responsible for this was my 12th PhD student, Dr Zhengrong Shi. While working for one of our spin-off companies, he became impatient to put the knowledge gained in our labs into practice. Although

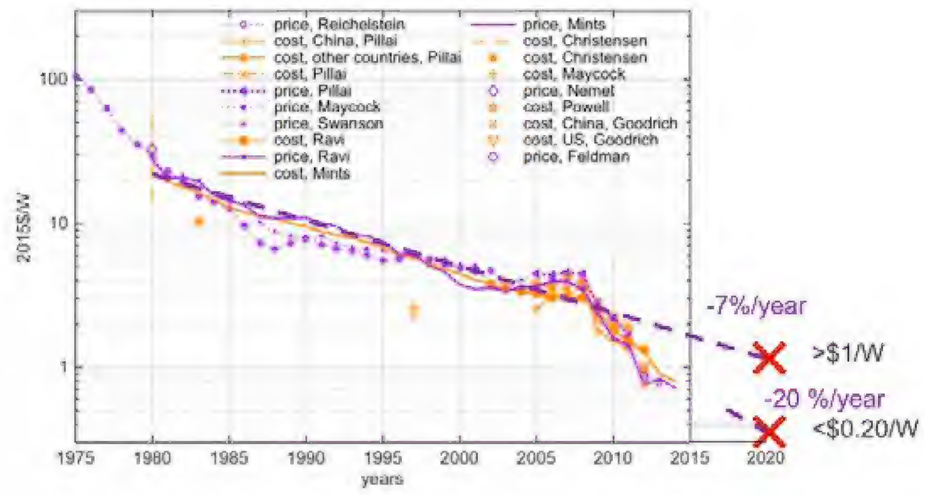

Figure 13: History of photovoltaic module prices and costs. Note the breakpoint circa 2008 (modified from Kavlak et al., 2018).

by now an Australian citizen, he learnt of improved opportunities for private companies in China in the late 1990s and decided to set up cell manufacturing in China, then completely devoid of all appropriate infrastructure. The chart in Fig. 14 shows the rapid reduction in average wholesale selling price since 2008 on a linear scale due to his initiative, showing 5 distinct periods (also shown on a semilog scale since 2012 in the inset).

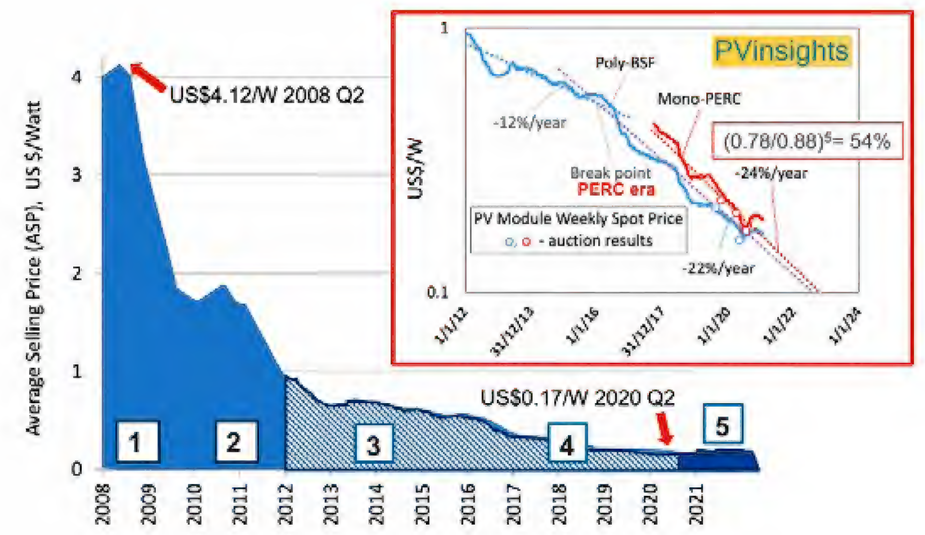

Figure 14: Module average wholesale selling price reduction since 2008 showing five distinct cost reduction periods (1: Competition between US-listed private Chinese companies; 2: Chinese state-owned companies unsuccessfully attempt to enter market; 3: Chinese government supports market development; 4: PERC enters the market and accelerates cost reduction; 5: Recent supply-constrained period). The inset shows reduction since 2012, showing how PERC reduced prices by nearly 50% compared to a "business as usual" scenario.

After rejection by several cities, the Wuxi government finally encouraged local companies to invest a total of US$6m in his initiative. With this, Zhengrong set up the first commercial cell manufacturing line in China, with help from former and current members of our team including myself, who got to cut the ribbon at the gala opening ceremony (Fig. 15). Zhengrong did well, aided by the rapidly growing market, largely due to Germany's trail-blazing feed-in tariff program, with Zhengrong investing profits into rapidly expanding his production.

Figure 15: The opening of Zhengrong's historic first production line in 2002, the first commercial solar cell manufacturing line in China (Green, 2016).

His progress was noted by US investment banks, Morgan Stanley and Goldman Sachs, looking for promising Chinese companies to list on US exchanges, given the interest in Chinese stocks in this era. They helped organise a management buy-out of the original Chinese investors, followed by listing of his company, Suntech, on the New York Stock Exchange at the end of 2005, the first private China-based company to list on this exchange. This listing was a huge success, raising $400m, the biggest tech float of 2005, making Zhengrong the "first solar billionaire" since still owning most of the company. Goldman Sachs also made at least $200m on the exercise. This created an avalanche of listings as investment banks looked for China-based solar companies to list as Suntech clones and solar companies eagerly sought such windfall investment. The first six company listings are shown in Fig.16, with UNSW-trained staff circled, either founders or recruited as CTOs to meet the investment banks' due diligence requirements. Over $7bn was raised by the 10 companies listing between 2005 and 2010, invested largely into manufacturing capacity, with 7 of these companies still presently in the top-10 worldwide, forming the backbone of the present industry. Six of these 7 had UNSW-trained staff either as founders or CTOs on listing (Green, 2016).

Figure 16: The first six of the ten Chinese-based photovoltaic companies to list on US exchanges between 2005 and 2010, triggered by Zhengrong's 2005 listing. UNSW-trained staff are circled.

The competition between these cashed-up companies caused prices to drop rapidly as they battled for market share. The strongest survived in the much lower price regime that resulted. At this stage, the Chinese government realised the huge asset it had in its solar industry and began supporting its continued growth by market development programs that have accounted for a large fraction of annual installations globally since 2012. This has had several positive

outcomes, including accelerated cancellation of China's plans for new coal-fired plant and driving down solar costs to present low levels.

During this phase, cost reduction was a reasonably steady 12%/year, as seen by the fit to the blue line in the upper right graph in Fig. 14. After 2016, this rate nearly doubled to 22%/year, due to the pressure on prices as the incumbents battled to maintain market share against rapidly encroaching PERC technology. We can estimate that PERC reduced prices to 54% of what they would have been in a "business-as-usual" scenario, projected at the different rates as before.

The International Energy Agency (IEA) previously saw little role for solar in our energy future, with the situation changing completely in 2020 when the IEA recognised that solar now provides "the cheapest electricity in most countries," in fact "the cheapest electricity in history" under favourable circumstances (IEA, 2020).

Recent market drivers

Finally, I'll talk about recent market drivers, with the industry now experiencing rapidly increasing demand, with this situation expected to be maintained until at least 2030.

In its most recent roadmap for combating climate change, the IEA calls for immediate scaling-up of solar and wind rapidly over the rest of this decade. Globally we reached one terawatt of installed solar early in 2022 — the roadmap calls for 5 TW by 2030 corresponding to an average of half a terawatt/year installation, twice that expected in 2022 (IEA, 2021).

The Intergovernmental Panel on Climate Change (IPCC) also previously saw a limited role for solar, but their most recent report released in April 2022 evaluated mitigation options, their costs and their potential for impact by 2030 (IPCC, 2022). The report listed many options, with the most important of these being those that can be implemented at zero or negative cost. Such options included changing our transport fuels, but solar was found to have the most potential for reducing CO_2 emissions by 2030 at zero or negative cost, with even larger impact at small marginal cost.

Annual solar installations are expected to reach a quarter of a terawatt in 2022, doubling from 3 years earlier. Due to the factors listed, we expect the growth to be even faster over the rest of this decade, with at least two doublings by 2030, taking us up to 1 TW/year annual installation, some think by 2027. The chart in Fig. 17 that I marked up in 2015, shows the problem we face in keeping global temperature rise to reasonable levels. Despite the best efforts of the four biggest emitters, they alone appeared likely by 2030 to consume the whole allocated budget to maintain global temperature rise to 2°C. However, if installing 1 terawatt/year of solar by then, this can recover the targeted trajectory, if displacing coal from electricity generation or oil from transport.

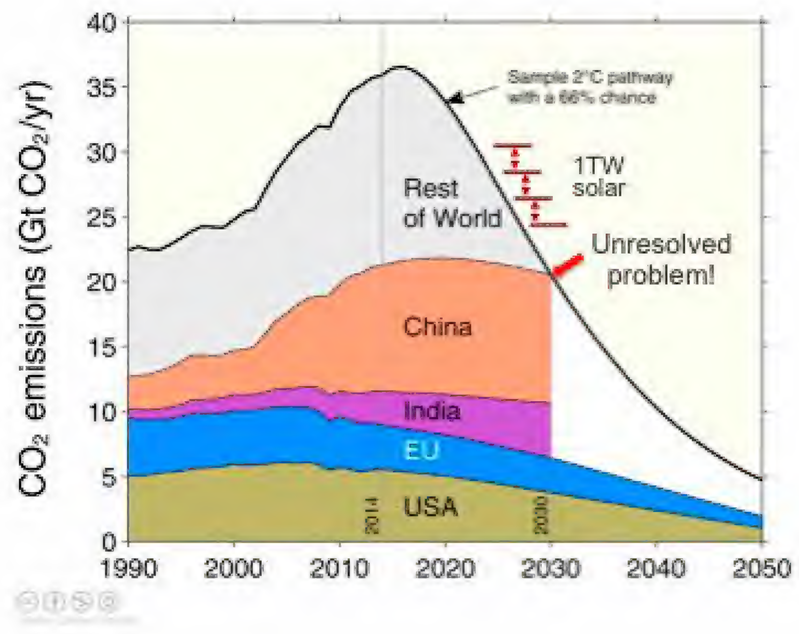

Figure 17: Historic CO_2 emissions to 2014 and a projected emissions trajectory to limit global temperature rise to 2°C (modified from Global Carbon Project, 2015).

Conclusion

In summary, we are proud that our work has positioned solar to make an immediate and major impact on climate change mitigation. Our four main contributions have been increasing silicon solar cell efficiency by 50% relative, holding the record for cell performance for 30 of the last 39 years, with several of the approaches explored during this phase now being used in commercial product. We are also proud to see the impact that our PERC cell technology has had upon recent prices and the role that our former students have played in triggering a major manufacturing transformation that now makes solar the cheapest source of electricity in history, according to the International Energy Agency. Our world-first undergraduate engineering degree program has also supplied well-trained graduates to fuel the very rapidly expanding industry.

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Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, pp. 182–188. ISSN 0035-9173/22/020182-07

Quis custodiet ipsos custodes? From quantum gravity to second-order cybernetics

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Abstract

This brief note will discuss an interesting byway that emerged from my historical and philosophical research on quantum gravity (for which I was awarded the 2021 History and Philosophy of Science Medal of the Royal Society of NSW). The byway in question concerns the seemingly essential role played by observers (or subjectivity) in our models of reality. That is, the deepest probing of reality in fundamental physics (which quantum gravity research amounts to), suggests a necessary role for humanity, or something like it. Science is truly a human story on this account.

> We have found a strange footprint on the shores of the unknown. We have devised profound theories, one after another, to account for its origins. At last, we have succeeded in reconstructing the creature that made the footprint. And lo! It is our own. — Sir Arthur Eddington, *Space, Time, and Gravitation*, Cambridge University Press, 1920, p. 200)

Readers with a fondness for the classics will immediately recognise the above phrase in my title from Juvenal's *Satires* (Satire VI, lines 347–348): "Who watches the watchers?" The implication being, of course, that somebody *should* watch those watchers! This is, most will agree, general good-sense, unfortunately not heeded nearly enough in our political hierarchies and, according to some scientists, not heeded enough there either.[1] Within the former context, the concern is over tyrannical rulership, and the latter concerns, as we shall see, another sort of tyranny that we might label "the tyranny of objectivity." The English astrophysicist Sir Arthur Eddington (1882–1944) used this latin phrase as a rather neat summation of his idiosyncratic scientific epistemology, interpreting it as: "Who Observes the Observers?" That is: since all empirical science starts from our immediate experience (how can it be otherwise?), and spreads out by inference to everything else, no matter how remote (see Eddington, 1928, p. 281), then how are we to account for this elementary fact within science and our scientific theories? We must seemingly pretend that we do not exist and that the universe would go on being its same old self in our absence.

1 Juvenal's discussion was itself a (*very* politically incorrect, by present standards) skit on why men should not get married to women, given the nature of women (which he proceeds to outline in a way that would make even Jordan Peterson blush), especially when there are far more pleasant alternatives available, such as committing suicide. The line about who watches the watchers refers to the clever expedient of having a eunuch watch one's wife. And you thought the MGTOW movement was a recent thing? It was Edmund Burke who in 1756 applied the phrase to government, and the idea that because of the 2nd-order watcher problem we should do away with any and all forms of government in favour of a "natural society against politicians".

Eddington spent his final years working on what he believed was a *truly fundamental* theory, in which the human contributions were fully worked out, so that the invariant structure of the universe (purged of human epistemology) could be laid bare.[2] Eddington lectured on this material at Dublin, producing a pamphlet *The Combination of Relativity Theory and Quantum Theory* (1943) which contains the basic ideas of his *Fundamental Theory*. At the same time, in 1943, and in *his* lectures to the Dublin Institute for Advanced Study (converted into the book *What is Life?* a year later), the physicist Erwin Schrödinger pointed to Albrecht Dürer's painting *All-Saints*, in which we find two circles of believers gathered in prayer around the Trinity elevated in the skies, a circle of the blessed ones above, and a circle of earthbound humans. Within the earthbound humans we find kings and emperors and popes, and, he notes, we also find a tiny portrait of the Dürer himself, figuring as "a humble side-figure that might as well be missing" (1944, p. 137). Similarly, in science we find our models "colourless and soundless and unpalpable".[3] Schrödinger would later refer to this curious omission of the source of knowledge as an "exclusion principle" of sorts radically distorting this knowledge of the world if not taken account of.

The philosopher Edmund Husserl labeled this abstractive methodology "the Galilean style," which, as Steven Weinberg puts it, involves making "abstract mathematical models of the universe to which at least the physicists give a higher degree of reality than they accord the ordinary world of sensation" (1976) — Husserl called the latter world "the life-world." This style is often aligned with the so-called Copernican Principle, stating that we, as observers, do not occupy a privileged position in the cosmos. Yet we forget that the Galilean style is, when viewed more closely, a slap in the face of the Copernican Principle, since it assumes the world we observe is how it is, rather than involving features of the observers themselves. The Galilean style abstracts out too much, and ends up leaving the observer so privileged that we assume we can ignore it, treating it as part of the background. A more thoroughgoing scientific Copernicanism would involve including the standpoint of knowledge-creation or discovery within its models, which would also thereby tame some of the more hubristic elements of modern science.[4]

2 This book was published in its unfinished state as *Fundamental Theory* by Cambridge University Press in 1944. I have discussed his viewpoint in many places, including Rickles (2017) and (2020).

3 Lest the objection that science's ethos involves replacing observers with instruments, with none of the flaws of observers, Schrödinger writes (in his later Tarner Lectures, *Mind and Matter*): "the observer is never entirely replaced by instruments; for if he were, he could obviously obtain no knowledge whatsoever" (1955, p. 162). I would also add that those instruments do not come out of nowhere: they are infused with theoretical assumptions that must be in place for us to believe that they reveal what we take them to reveal: they are themselves 'embodied theories.'

4 This more integrated approach aligns somewhat with Iain McGilchrist's ideas (e.g. in his book *The Master and His Emissary*: Yale University Press, 2012) of the brain's two hemispheres (which also stand symbolically for the world at large, as a kind of East and West), which should be synchronised in order to avoid the excesses of either being dominant (and so balancing subject and object; reason and feeling, and so on).

We find the foregoing sentiment expressed in the cyberneticist Heinz von Foerster's marvellous phrase[5]: "Objectivity is the delusion that observations could be made without an observer."[6] The so-called scientific method makes essential reference to observation, and yet we forget this when it comes to our theories. Both Eddington and von Foerster appear to have shared the same view about the foundations of the scientific enterprise: you must take due account of the observer if you want to properly understand the business of science *and* its produce. The cybernetic approach to systems (including science), specifically when viewed from a meta- or 2nd-order perspective, takes the role of the observer-participator (i.e a bounded, purposive system) seriously in the models we make of the world. It is curious, then, that our models of ordinary systems (such as social systems) appear to now be converging on the same conclusion as our models for the most non-ordinary systems (those of quantum gravity).[7] I will try to explain a little of the overlap here, though to go into detail would require a book.[8]

While von Foerster thought in terms of computational processes (inputs, outputs, and feedback), Eddington, true to his times (and with the likes of Bertrand Russell nearby) thought in terms of *sense data*. But the same problem faces both accounts: what is the nature of scientific epistemology given that it must come from such finite beings, as we are? This is essentially epistemology viewed as a sampling problem. We are dropped into a potentially infinite desert, with no innate map and compass telling us how the world around us really is, and must orient ourselves somehow from our personal data stream of (what we suppose is) a mere fraction of all possible grains of sand. Science, like everything else beyond our personal screen, is a grand exercise in inference. Moreover, even as we develop our scientific theories to help us navigate in this desert, we never get beyond these representations (or maps).

Interestingly, this basic idea (going back at least as far as Hermann von Helmholtz), of the brain as an inference-engine, making best-fit guesses from a data stream, is, like cybernetics, making a strong comeback, with Karl Friston's notorious 'free-energy' approach, with the associated predictive processing/Bayesian brain elements. These approaches share the same tendency to focus the attention of where knowledge is being created (the mind or brain). It considers the possibility that much that we take to be objective about the world out there, is a result of mechanisms that allow us to navigate the world, and might have more to do with Us than It. However, ultimately, it

5 See Ernst von Glaserfeld (1996, p. 279).

6 See Lynn Segal's book (Segal, 2001) on von Foerster for an excellent account of those aspects that relate to this paper.

7 This is not an historical statement, but one that describes the present conditions in quantum gravity research. I am currently engaged, with a PhD student, on a study of Stephen Wolfram's new theory of quantum gravity (involving the space of all possible computational rules) which, again, must, if it is to recover the universe we experience, involve the introduction of computationally-bounded observers that sample this space (see, e.g. https://writings.stephenwolfram.com/2021/04/why-does-the-universe-exist-some-perspectives-from-our-physics-project/ for Wolfram's viewpoint).

8 Some of the philosophical background can be found in Atmanspacher and Rickles (2022) — though there we speak in terms of action-perception cycles, information, and meaning, rather than implicitly cybernetics terms.

breaks down the Us/It distinction, since we become part of the system to be modelled (that is, we model the modeller and use this to understand the models [i.e. theories] that the modeller generates).

Eddington argued, given such ideas, that the theories that result from our observations take on a Procrustean flavour. The physicist, on this view,

> Might be likened to a scientific Procrustes, whose anthropological studies of the stature of travellers reveal the dimensions of the bed in which he has compelled them to sleep. (1936, p. 328)

As Procrustes would make sure any travellers visiting his establishment would fit his 'one size fits all' bed (by stretching them out or chopping their legs off), so the scientist achieves the comprehensibility of the universe by selecting out those parts that *make* it comprehensible. This view Eddington labels "selective subjectivism." We find cyberneticists, such as von Foerster, using "radical constructivism" to describe much the same thing. Likewise, Wheeler's phrase "It from Bit" (on which more below), and his later followers' "participatory realism." Henri Poincaré, in *The Value of Science*, had earlier presented a similar view of the nature of laws and order as part of his thesis of conventionalism. Thus, he writes: "Does the harmony which human intelligence thinks it discovers in nature exist apart from such intelligence? Assuredly no. A reality completely independent of the spirit that conceives it, sees or feels it, is an impossibility".

It is important to note that both Eddington and Wheeler were led to their views by a deep knowledge of the gaps in our foundations of physics, namely the theories of relativity and quantum theory. Because Wheeler, and many other quantum gravity researchers, are on a quest to figure out the deepest structures of our world, they tend to view our current frameworks as *provisional*. It is fairly easy to see how Eddington was led down this path, through his study of Einstein's theories of relativity. For Eddington, these revealed in stark detail the essential role of the observer (the reference frame in this context) in properly interpreting the results and making sure they are physical, rather than mere artefacts of representation. A huge controversy in the early part of classical and quantum gravity research was precisely over whether gravitational radiation (since detected, with a pair of black holes, with Nobel prizes duly awarded) is representation or reality. That is, the result needed to be disentangled from the coordinates an observer uses to describe a gravitating system.

Wheeler's view came more from the side of quantum mechanics, though mixed up with the idea of background independence that we find in the general theory of relativity — i.e. the notion that there are no absolute structures in general relativity, so that all physical quantities must be relational in form. This is sometimes expressed in terms of there being no spacetime existing as a fixed stage on which the actors (matter and energy) play out some performance. Rather, spacetime (the stage) is one of the actors itself. Wheeler essentially extended this to include observers too: they are part of the relational structure, and should not be viewed as standing apart from the stage production, as audience members. But Wheeler also viewed Niels Bohr as the sage of quantum mechanics, and in particular took his view "No elementary phenomenon is a phenomenon until it is an observed phenomenon" as the basic principle of

quantum mechanics. In other words, there is nothing *manifested* in the world (indeed, no world at all) until an observation is made (by a reflecting subject) that *objectivises* it.[9] Hence, there is a kind of relativity or duality (between subject and object) in quantum mechanics too.[10] But for Bohr this was no problem since physics was not concerned with probing deeper than the manifest reality (since such a thing cannot be probed in this way). As he claimed: "In our description of nature the purpose is not to disclose the real essence of the phenomena but only to track down, so far as it is possible, relations between the manifold of our experience" (1934, p. 18).

Wheeler was drawn into *quantum gravity* by the ineluctable logic of following the theory of gravitational collapse into its extreme limit. He couldn't resist probing deeper beyond the manifest, to try and figure out what made it go. Pre-geometry, which is really just pre-physics, is the natural outcome of this route. Why? Because a gravitational collapse of the universe is capable of eliminating everything in its big crunch: all of space, time, matter, *and* law. If so, what sense are we to make of space, time, matter and law, making up our cosmos? Wheeler believed that we must seek a deeper theory of "cosmogenesis" beyond the black hole and beyond the big bang. These cannot be fundamental elements of reality. In understanding the deeper underpinnings of physics, in such a world, John Wheeler notes that:

> In brief, we confront two imperatives and one great issue. First, the gates of time tell us that physics must be built from a foundation that has no physics; or still more briefly: "Must Build." Second, elementary quantum acts of observer-participatorship: "Do Build." Finally, how are billions upon billions of these elementary building acts organized — if they are to make up the grand structure that we call "reality"; or, in brief: "How Build?" No more attractive clue offers itself for attacking this great issue than the way information is processed to make "meaning." On what else can a comprehensible universe be built but on the demand for comprehensibility? (Wheeler, 1980, pp. 6–7)

Comprehensibility by whom? Us, of course — hence, 2nd-order cybernetics. Where there is information, there is meaning. Where there is meaning, there are creatures like us required to interpret it. Since Wheeler's viewpoint (known colloquially as "It From Bit") puts information and meaning at the very deepest layer of reality, we must also place there the *interpreters* that provide meaning to the bit strings. Interestingly, this view of information as the correct fundamental ontology of the world is becoming near-orthodoxy — developments in CRISPR, AI, quantum information theory, and so on, are propelling this view to the centre even more.

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9 We should not underestimate Bohr's deeper views, especially on account of his decision to embed the *Taijitu* (Yin-Yang) symbol at the centre of his coat of arms. Bohr strongly believed that without a subject there was no object, and vice versa. It was this aspect of Bohr's approach to quantum mechanics that so disturbed Einstein, *not* the probabilistic nature of the theory.

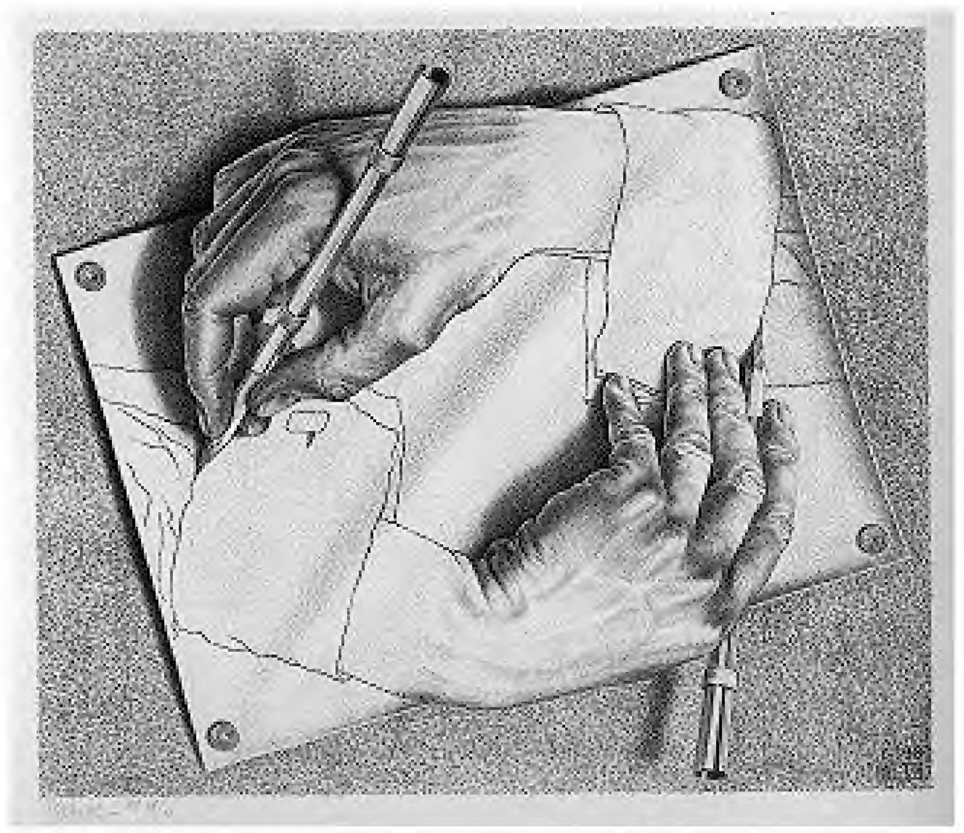
10 We can find several others espousing variations on a theme of this basic idea of reintroducing the subject or observer, e.g. David Bohm and more recently the cosmologist James Hartle, with his scientific model of an observer known as an IGUS: an "information gathering and utilising system." But it remains the exception rather than the rule.

But, to repeat, it is not correct to say that the world is *made of information*. The world outside of such creatures as Us does not contain *any* information as such since it involves a relation between It and Bit and Us.[11] The science of information developed by Claude Shannon and Warren Weaver (1949), especially as presented today, might have you believe that things are otherwise, but we must remember that Shannon was concerned with transmission efficiency and the elimination of redundancy to achieve this. Yet even in Shannon's works, for example on the identification of redundant elements from messages to code more tightly, the criterion for removing redundancy must be referred to a criterion of synonymy that ends with Us once again. Without Us, there is no way to distinguish one bit string from another; nor is there a way of seeing how one and the same bit string can represent an infinitude of possibilities.

As in cybernetics, this way of thinking often leads to loops and cycles. Roger Penrose puts the circuit (which Wheeler calls the "meaning circuit") linking subject (epistemology) to object (ontology) as follows:

> We have a closed circle of consistency here: the laws of physics produce complex systems, and these complex systems lead to consciousness, which then produces mathematics, which can then encode in a succinct and inspiring way the very underlying laws of physics that gave rise to it. (Penrose, 2004)[12]

If we take this participatory view of reality seriously we face a kind of construction by us that in turn constructs us, with each pulling the other into being much as Baron von Munchausen pulls himself and his horse out of a swamp by his own hair.[13] As if mirroring the Eddington quote with which we began, let us close with T. S. Eliot: "The end of all our exploring will be to arrive where we started."



Drawing Hands — M.C. Escher

11 However, in the aforementioned book (Atmanspacher and Rickles, 2022) we make a case for a kind of primordial or latent meaning that sits underneath both It and Bit, and subject and object.

12 Penrose writes elsewhere "We are all part of the world, and we are conscious beings, so if the world is itself describable mathematically, then this whole idea of conscious perception must be describable mathematically" (interview of Penrose with Alan Lightman, 1989: https://www.aip.org/history-programs/niels-bohr-library/oral-histories/34322). This kind of 'One World' framework is very much influenced by quantum gravity research whose entire motivation is on the idea that, despite the lack of direct empirical evidence demanding such a theory, since there is one world, there should be a framework that can handle quantum and gravity together. To expand out to consciousness is just another step.

13 The picture *Drawing Hands* of Maurits Cornelis Escher (see figure) provides a perfect visual representation of this co-creation. What's more, it constitutes a kind of new existentialism (quantum existentialism) since, existentialism in its orthodox sense refers to the absence of absolute essences. There is no ready-made world out there. This can be translated into the idea that the division between subject and object is not fundamental, with subjects as much as objects involved in the world's construction.

Acknowledgements

I am very grateful for funding from: The Foundational Questions Institute and Fetzer-Franklin Fund, a donor advised fund of Silicon Valley Community Foundation [FQXi-RFP-1817]; The John Templeton Foundation [Grant ID 62106]; and the Australian Research Council [Grant DP210100919].

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Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, pp. 189–192. ISSN 0035-9173/22/020189-04

Lessons from a pandemic

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Abstract

Peter Shergold and others undertook a study of Australia's response to the COVID-19 pandemic. This is a private report, and as such is able to make observations which would be precluded from a government report.

Introduction

The story of Australia during COVID-19 will depend on who's telling it. For some, it's a story of inconvenience. It's a narrative of cutting our own hair, struggling to exercise, and endless Zoom meetings. But for others, it's a story of trauma. It's a tale of lockdowns in overcrowded housing, job loss, deteriorating mental health, isolation and domestic violence. It's a story of losing loved ones and missing final goodbyes.

These were the heartbreaking stories Jillian Broadbent, Isobel Marshal, Peter Varghese and I[1] heard as we undertook our Independent Review into Australia's Response to COVID-19.[2] The Review was a first for Australia. Its terms of reference were not set by a politician. It was entirely independent of government. It was philanthropically funded. It was apolitical. The more than 350 people who participated in the Review were not compelled to appear. They did not feel obliged to defend a decision in public. Their evidence was entirely confidential. They participated because they wanted to help answer the Review's core question: What can Australia learn from the pandemic to be better prepared for the next health crisis?

Reflections on the pandemic

We did not seek to ascribe blame. Politicians and public servants did their best in the fog of uncertainty in which they had to make decisions. We titled the Review *Fault Lines* because this is what COVID-19 exposed. The crisis exacerbated inequalities. It exposed vulnerabilities. The adverse consequences of the pandemic were not distributed equally.

Our consultations, research and analysis have led us to a number of findings and recommendations — some specifically related to health, such as the need for an Australian Centre for Disease Control and Prevention, but others that go more broadly to improve our crisis responses in a range of situations.

With towns and suburbs counting the cost of the ongoing floods, La Niña threatening much of the country over spring and summer, and the certainty of new corona-

1 Sharon Lewin AO was initially appointed to the Panel but subsequently chose to step down to ensure there were no perceived conflicts of interest from her participation.

2 Shergold, P., Broadbent, J., Marshall, I., and Varghese, P. (2022) *Fault Lines: an independent review into Australia's response to COVID-19*, Analysis & Policy Observatory, October 20, https://apo.org.au/sites/default/files/resource-files/2022-10/apo-nid320067_0.pdf

virus variants on the horizon, we know the next crisis is never far away. Our review shows there is an urgent need to improve government decision-making through broader advice and greater transparency.

While governments need to react quickly, the COVID-19 experience too often reflected decisions made on the run by a limited group, neglecting the goldmine of experience and knowledge that business groups, frontline workers and those with lived experience can offer. When given the opportunity, businesses, unions, and civil society worked closely with government, providing real-time data and on-the-ground information about what was happening in the community. They worked hand in glove with all levels of government to identify problems and solutions to help overcome them.

Unfortunately, this close liaison often came only after problems became evident: a key reason we should establish a panel of multidisciplinary experts and representatives (not just health experts) to advise governments during crises.

We also need to publicly release the modelling and evidence used in government decision-making. Transparency creates trust, and while we all became "armchair epidemiologists" during the pandemic, information is critical to building confidence in the policy response.

Similarly, there is much we can do to improve the scope and standard of government communication. The national cabinet should expand the channels of communication in times of crisis and improve the methods of communication, particularly with those from culturally and linguistically diverse backgrounds.

We also need to improve public service capability, including the collaboration of public servants across jurisdictions. Many told us that the pandemic strengthened their informal connections across jurisdictions, but that started from a low base and will probably fade again over time. They bemoaned the next crisis, which will likely see new delegates and decision-makers having to rebuild these connections from scratch.

We need to build a culture of evaluation and learning in the public sector to ensure we are making progress. Our review recommends establishing a politically independent Office of the Evaluator General to assess which policies work, which don't and how they can be improved, particularly in a crisis.

Australia got many things right in its handling of COVID-19, but we also got some major things wrong — with results that cost lives and livelihoods and will have repercussions for years to come.

We must address societal fault lines in our decision making, especially in a crisis. This was the core finding of our Review.

Australia got many things right. The financial support extended was important. So was our initial health response to such an uncertain disease. But we got four consequential matters badly wrong.

Four areas where we should have done better

First, economic supports should have been provided more fairly. Casual workers, migrants and international students should not have been excluded. Sick leave should have been immediately provided to all workers, JobKeeper should have had a clawback mechanism for employers whose profits rose significantly.

Second, lockdowns and border closures were overused. Initially these are useful measures to buy time and prepare. But many were the result of policy failures in quarantine, procurement of vaccines and equipment, contact tracing, testing and disease surveillance. Too many were guided by politics.

Third, school systems should have stayed open. Closing schools was a mistake when we knew that children were unlikely to be severely ill when infected and that schools were low-transmission environments. The costs of educational disruption and increased mental stress will continue for years.

Fourth, older Australians should have been better protected. Making it difficult for aged-care residents to transfer to hospital when they contracted COVID-19 was a mistake. It cost many lives.

Five overarching lessons

We take five lessons from these shortcomings:

- First, we must have societal fault lines front of mind when we make decisions;
- Second, we must better plan, prepare and practice for future health crises;
- Third, we must avoid the perils of overreach;
- Fourth, we must be transparent, clear and consistent in making and communicating decisions; and
- Fifth, we must better balance competing trade-offs between health, social and economic outcomes.

It's not enough to note these lessons. Building these lessons into institutional structures is the goal of our six recommendations.

Six recommendations to put societal fault lines at the centre of improving our response to the next health crisis

First, we need to strengthen crisis preparation, planning and scenario testing. Australia's pandemic plans were not regularly tested. Many key actors didn't even know they existed. It's little wonder they were quickly discarded. Failing to plan is planning to fail.

Second, we need an expert body and trusted voice on public health. We need a fully independent Australian Centre for Disease Control and Prevention, with complete access to national data. Australia is the only OECD country that doesn't have one.[3]

Third, we need to improve government decision-making. We should establish a panel of multidisciplinary experts and representatives — not just health experts — to advise governments during crises. We should better harness the frontline experience of business, unions, the community sector and local government. We also need to publicly release the modelling and evidence used in government decision-making. Transparency creates trust.

Fourth, we need to enhance public service capability. It is imperative that governments authorise better collaboration between jurisdictions and strengthen their collective capabilities, particularly in data, digital skills and communication.

3 See Holmes, E. (2019) The future of biosecurity in Australia, *J. & Proc. RSNSW*, 152: 121–128. https://royalsoc.org.au/images/pdf/journal/152-1-Holmes.pdf

Fifth, we need to significantly enhance how governments use data. We must improve the collection, linking and sharing of real-time data while keeping it safe and protecting privacy. Only then can we adapt our crisis response as new evidence comes to light.

Finally, we need to build a culture of evaluation and learning in the public sector. We should establish a politically independent Office of the Evaluator General to assess which policies work, which don't and how they can be improved, particularly in a crisis.

Conclusion

We must address societal fault lines in our decision-making, especially in a crisis. The pandemic exposed vulnerabilities and exacerbated inequalities, with adverse consequences that were not distributed equally among us. Putting people at the centre of our crisis response is critical. We cannot overlook those who are most vulnerable. We must apply this to the current flood situation and other crises, as history shows disaster often entrenches disadvantage and indeed often hits those who are already struggling.

It's not enough to note these lessons and let the report join others on the bookshelf. Building these lessons into institutional structures is the goal of our recommendations.

Australia's next disaster needs broad teams of experts in place and public servants who can talk easily across state and federal boundaries. The wisdom of hindsight only comes if we have the wisdom to seek it. We won't be prepared for the next pandemic if we don't learn from the current one. And one thing is certain: there will be another.

Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, pp. 193–197. ISSN 0035-9173/22/020193-05

Building Australia's AUKUS-ready nuclear workforce

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Abstract

Introducing nuclear-powered submarines will be one of the biggest workforce development challenges Australia has faced. It can be done, but it will need a new approach and there's no time to waste.[1]

Introduction

Good afternoon, everyone. I'd like to start by acknowledging the traditional owners of the land we meet on today, the Ngunnawal and Ngambri peoples, and pay my respects to their elders past and present. I'd also like to thank SIA President, Michael Fitzgerald, and the Executive Committee for allowing me to be part of this excellent conference program.

The announcement of the AUKUS partnership in September 2021 was dominated by the plan for Australia to acquire a fleet of nuclear-powered submarines. This was big news for the Institute and its members, but it was also big news for the university sector.

The challenge

Nuclear-powered submarines are some of the most complex machines human beings have ever developed. Bringing a fleet of these into service will be one of the biggest training and workforce development challenges Australia has faced. As the Defence Minister, Richard Marles, has said, AUKUS will demand a transformation in Australia's cultural relationship with science and technology.

Our AUKUS partners expect Australia to pull its own weight and develop sovereign capability to operate and maintain the fleet. This will require the integration of military, industry, government and academia to create an entirely new sector of the economy. The task goes beyond training the crews of future submarines. We can't just acquire nuclear technology without being able to provide best-practice nuclear stewardship. The challenge includes building the nuclear knowledge across all elements of the enterprise including corporate, nuclear physics, engineering, legal, policy, security and human resources across government and industry.

Australia has a strong international track record as a contributor to nuclear non-proliferation policy and a reputation as a responsible global citizen. But a fundamental uplift is required to develop the nuclear mindset required to be the custodian of this technology.

Australia has the expertise and capability. What we don't have yet is the scale to deliver the graduates and skills in the quantities required. We can do this. But it requires deliberate urgency. The time from now until

1 This is an edited version of an address given to the Submarine Institute of Australia Conference, Canberra, November 9, 2022. A similar piece appeared in the *ANU Reporter*. Reprinted with permission.

the first submarine is ready to enter service gives us a window of opportunity to scale up our capacity. But decisive action needs to be taken now so that we can be where we need to be in a decade's time.

I was heartened by the Minister's comments acknowledging that even though the entry into service of Australia's first nuclear-powered submarine seems a long way off, he understands there is no time to waste. This challenge can't be left to Defence alone. It will need a whole-of-government commitment to identify the skills and resources required. It will need a new approach to partnering with the universities who will deliver the training.

STEM pipelines

In Defence circles there is often talk about solving capability gaps in the transition from one system to another. That is obviously a critical issue for Vice Admiral Mead and his team to deal with. But I'm here to tell you today that whatever submarine design ends up being chosen, we won't be able to build and operate it locally unless we address the fundamental issue of Australia's workforce capability gap. We all know how hard it is to recruit and retain skills in science, technology, engineering and mathematics, or STEM.

Recently, General Campbell and Secretary Moriarty announced a series of expanded employment benefits that are needed for Defence to remain competitive as an employer in an increasingly tight labour market.[2] This is consistent across all sectors that rely on these skills and Defence is no different.

The outlook is concerning. Only nine per cent of Australian year-12 students are currently taking higher mathematics and only another 17 per cent are taking intermediate mathematics. This is foundational knowledge needed for success in STEM fields. Compounding this, the Productivity Commission recently found the Job Ready Graduates program — the funding scheme that allocates Commonwealth funding for university degrees — creates flawed incentives and reduces the return to universities for offering STEM places. The strained labour market conditions we face in 2022 will cripple us in 2032 if we don't take urgent action now to grow our sovereign capability.

Our nuclear workforce will need to include not just engineers and physicists, but also lawyers, regulatory experts, specialist medical staff, naval architects and policy advisers to decision-makers.

There is opportunity within the challenge too. The scale of our skills needs means there is no longer any excuse for women remaining such a small minority of the STEM workforce. According to the Chief Scientist, women still comprise only 29 per cent of university STEM qualifications. The same can be said with students from disadvantaged backgrounds.

While the HELP system provides broad access to university, support for students from disadvantaged backgrounds is so low that most have no choice but to go to the university closest to home, not the one that best caters for their skills and interests. Capable students, whoever they are, need to be identified and incentivised to pursue careers in AUKUS fields. Many of these roles will require years of training and

2 The ADF workforce was about 77,000 at the beginning of 2022–23, 5.4% below what was required. [Ed.]

experience. As Vice-Admiral Mead noted recently in *The Australian*, starting today we need to set a 14-year-old schoolgirl on a path to be captain of Australia's first nuclear-powered submarine.

Let me illustrate how this plays out. To get undergraduates to study nuclear physics, we will typically bring them to campus at the end of year 10 for a summer science program. If we did one (which we are not) tailored for the AUKUS workforce requirements, this would deliver a new set of undergraduates starting their degrees in 2025. These students would finish their undergraduate degrees in 2029, but many would require at least a Master's degree (completed by 2030), or PhD (completed by 2033).

That schoolgirl will probably get her nuclear science education here in Canberra at The Australian National University. Why ANU? To start with, because the only practising experimental nuclear physicists at Australia's universities are at ANU. But more broadly, because this is what the ANU was established to do.

Recommendations

How can we build the AUKUS workforce? At ANU we have identified three things government should do now that will enable us to meet this challenge.

First, in order to build a national nuclear enterprise, government should establish and define nuclear stewardship as a Sovereign Industrial Capability Priority, or SICP, to provide investment certainty. These priorities are intended to ensure access to essential skills, technology, intellectual property, financial resources and infrastructure in critical areas to the Defence mission. Just like industry, universities require planning certainty to make investments in capability and course offerings.

ANU runs the only comprehensive nuclear physics program in the country. But scaling up that program will require upfront investments in infrastructure, facilities and academic recruitment that ANU cannot afford right now, and indeed no university in Australia can afford this. There must be a program of support; the de facto alternative — waiting for international student fees to return to previous levels — is unthinkable.

A formalised SICP for nuclear stewardship would signal the priority being placed on developing sovereign capability in nuclear education and research. It would support the universities who will need to play a central role in building the skills and knowledge base to make the investments required to produce the graduates required.

Second, government should consider establishing an AUKUS career pathways program to harness high-achieving school-age students and provide long-term development and career progression in critical skills. AUKUS will demand a stronger pipeline of students choosing to undertake university study in key fields.

Nuclear science should clearly be the first cab off the rank for this program, but this approach will also be necessary across the broader advanced capabilities of AUKUS including in cyber and computing, engineering, space and quantum physics.

An AUKUS pathways program, jointly developed with Defence, could feature a portfolio of tailored degree programs providing a pathway for students to gain qualifications in an AUKUS-related field and then progress to a position in Defence working on AUKUS programs.

Such a program could include:

1. Courses in strategic defence studies and national security being incorporated into STEM degrees to instil a strong understanding of the strategic drivers and applications of technical skills.
2. Assigned mentors from Defence and regular exposure to Defence leadership, to establish a connection to AUKUS programs from an early stage.
3. Processing security clearances for students while they are studying to enable real work experience and practical placement opportunities with Defence.
4. Guaranteed placement in Defence at the conclusion of the program, bypassing existing Defence graduate programs.
5. Interstate field trips and international exchanges with our US and UK partner universities to reinforce the trilateral partnership.
6. Guaranteed accommodation at a university hall of residence to overcome the barriers that exist for students relocating to study.

Degree programs with some of these features, tailored specifically for AUKUS priorities, will also assist the government as it begins the task of rebuilding the technical capability of the public sector. A pipeline of qualified recruits will support Defence to provide contestable advice to government. The reliance on private contractors will be reduced, delivering greater value for money over the long term.

Third — and this goes to the concept of this being a national mission, rather than just a task for Defence — government should remove the barriers it has created through funding rules that prevent universities from being more dynamic in meeting national capability priorities. The new government's Australian Universities Accord process presents an opportunity to look at how universities and government can work together to tackle the challenges we face as a nation.

Conclusion

To conclude, the introduction of nuclear-powered submarines will require substantial development of Australia's scientific and engineering capacity. We cannot afford to drag our feet on this. Building the sovereign, nuclear-literate workforce we need will require a pipeline of academic staff to deliver education and research at scale, and credible pathways to an AUKUS career that attract the best students from across the country. This is a huge workforce development challenge. It is one we can meet but it requires government to invest in, and partner with our universities now to build the capacity we need in the future.

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Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, pp. 198–201. ISSN 0035-9173/22/020198-04

The Bluefield Pumped Hydro Energy Storage Atlas

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Abstract

The Australian National University (ANU) has released its Bluefield pumped hydro energy storage (PHES) Atlas.[1] The Atlas lists 1500 sites across Australia where a PHES system could be constructed in conjunction with an existing reservoir.[2] The new Bluefield Atlas complements ANU's existing Greenfield Atlas (Stocks et al. 2020, Stocks et al. 2021) which lists 4,000 off-river PHES sites that are not linked to existing reservoirs, thus requiring two new reservoirs.[3] Basically, for the Bluefield Atlas we searched near every existing reservoir in Australia to find a potential matching reservoir site to form a PHES pair. Only one new reservoir is required for a Bluefield site.

Introduction

Pumped Hydro Energy Storage (PHES) entails two reservoirs spaced a few km apart at different altitudes (Blakers et al. 2021). On sunny and windy days water is pumped uphill from the lower to the upper reservoir. On calm days or at night, the water returns downhill from the upper to the lower reservoir to generate power. The same water goes up and down hill for 50 years or more.

Australia needs a lot of storage to support variable solar and wind electricity on the way to reaching its target of 82% renewable electricity by 2030.[4] PHES excels for overnight and longer storage, while batteries are preferred for storage periods of minutes to hours (Blakers, Lu, Stocks 2022).

Water and land needs for enough PHES storage to support a 100% renewable energy system are small (Blakers, Stocks, Lu and Cheng 2021). About 3 litres of water per day per person is needed for the initial fill of the reservoirs and to replace evaporation, which is about 20 seconds of a morning shower. About 3 square metres of land per person would need to be flooded, which is about the area of a double bed.

The Atlas

Bluefield PHES Atlas users can pan and zoom to visualise potential reservoirs in detail, at a resolution of 30 metres. Clicking on a reservoir produces a popup with detailed information about the reservoir, while clicking on the tunnel route connecting the two reservoirs produces a popup with information about the PHES system as a whole.

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1 https://re100.eng.anu.edu.au/bluefieldatlas/

2 See Blakers, Stocks, Lu and Cheng (2022)

3 https://re100.eng.anu.edu.au/index.html

4 https://www.alp.org.au/policies/powering-australia

The reservoirs in the Atlas are all outside national parks and urban areas. None of the 5,500 potential sites in our Bluefield and Greenfield Atlases requires a new dam on significant rivers.

Reservoir sizes shown in the Atlas range from 2 to 500 Gigawatt-hours (GWh) of energy storage. For comparison, the Kidston[5] and Snowy 2.0[6] (Fig. 1) PHES systems presently under construction are 2 and 350 GWh respectively, while the two PHES systems recently announced by the Queensland Government are 50 GWh (Borumba[7]) and 120 GWh (Pioneer-Burdekin[8]).

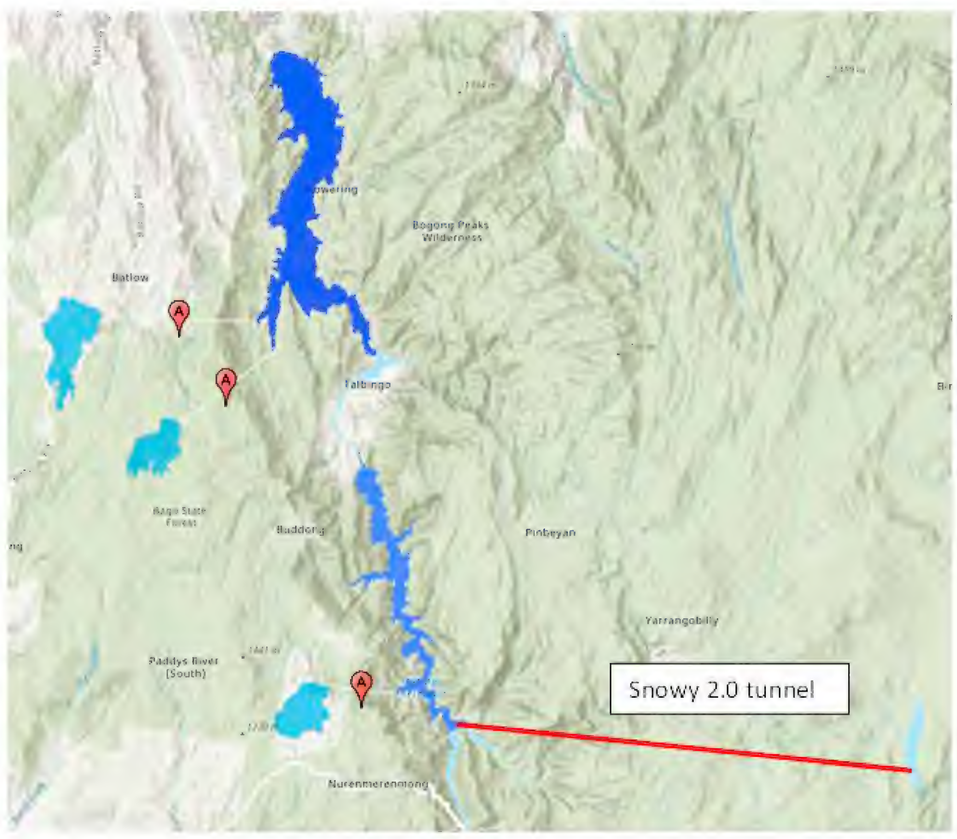

Figure 1: Class A, 500 GWh sites near Snowy 2.0

Each of the PHES systems in the Atlas is assigned a cost class (A through E), where an A-class system is expected to have half the capital cost of an E-class system per unit of storage. Australia has about 300 times more PHES storage potential than needed to support a 100% renewable energy system. We can afford to be choosy, and only develop the very best sites.

The PHES Atlas is routinely accessed by Government and companies. The Queensland Government recently announced the 5 Gigawatt Pioneer-Burdekin PHES system located at a site identified in our Atlas.

PHES provides about 95% of global energy storage. It is a highly credible, low-cost, mass-storage option to support rapid deployment of solar and wind. However, most of the existing PHES storage is co-located with hydroelectric schemes. The vast scale of storage opportunities that do not require new dams on rivers was unknown until our Atlas was released.

Findings in the Atlas

We found many interesting Bluefield sites. Large numbers of excellent sites of all sizes exist adjacent to Snowy 2.0 in the Snowy Mountains. This includes three 500 GWh potential reservoirs, which are more than enough to support a 100% Australian renewable energy system.

Figure 2: Detail of a Class A, 50 GWh site at Lake Windamere

5 https://genexpower.com.au/250mw-kidston-pumped-storage-hydro-project/

6 https://www.snowyhydro.com.au/snowy-20/about/

7 https://qldhydro.com.au/projects/borumba-pumped-hydro-project/

8 https://qldhydro.com.au/projects/pioneer-burdekin-pumped-hydro/

NSW: Lakes Pindari, Wyangala, Windamere (Fig. 2), Burrendong and Chaffey have attractive Bluefield sites to support NSW Renewable Energy Zones.

ACT: Canberra's main water supply dams, Cotter and Googong, both have possibilities.

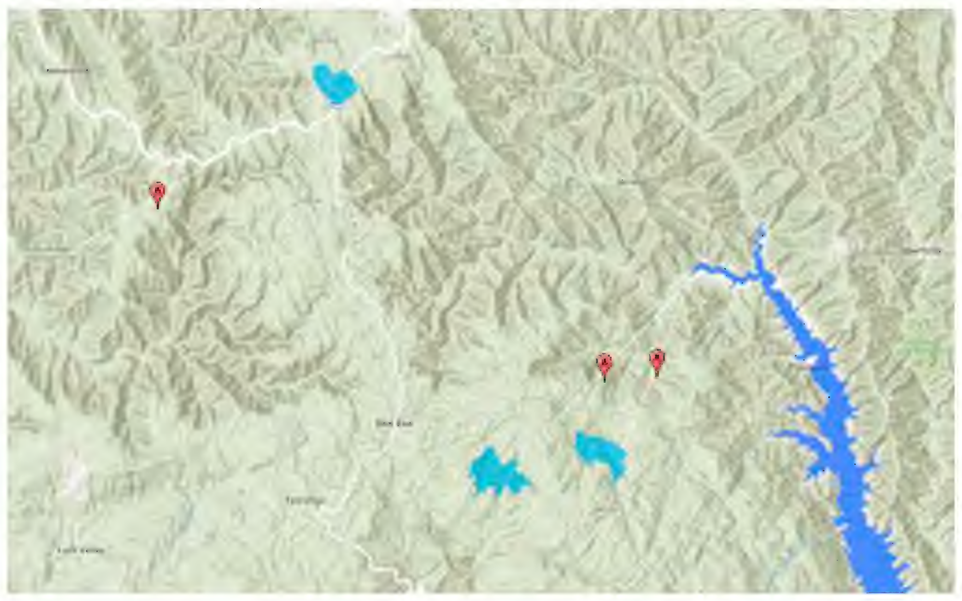

Figure 3: Three Class A 150 GWh sites at Thomson and Upper Yarra reservoirs

Victoria: Sites at Tarago, Maroondah, Nillahcootie, Rocky Valley, Upper Yarra and Thomson (Fig. 3) can support large-scale offshore Victorian wind.

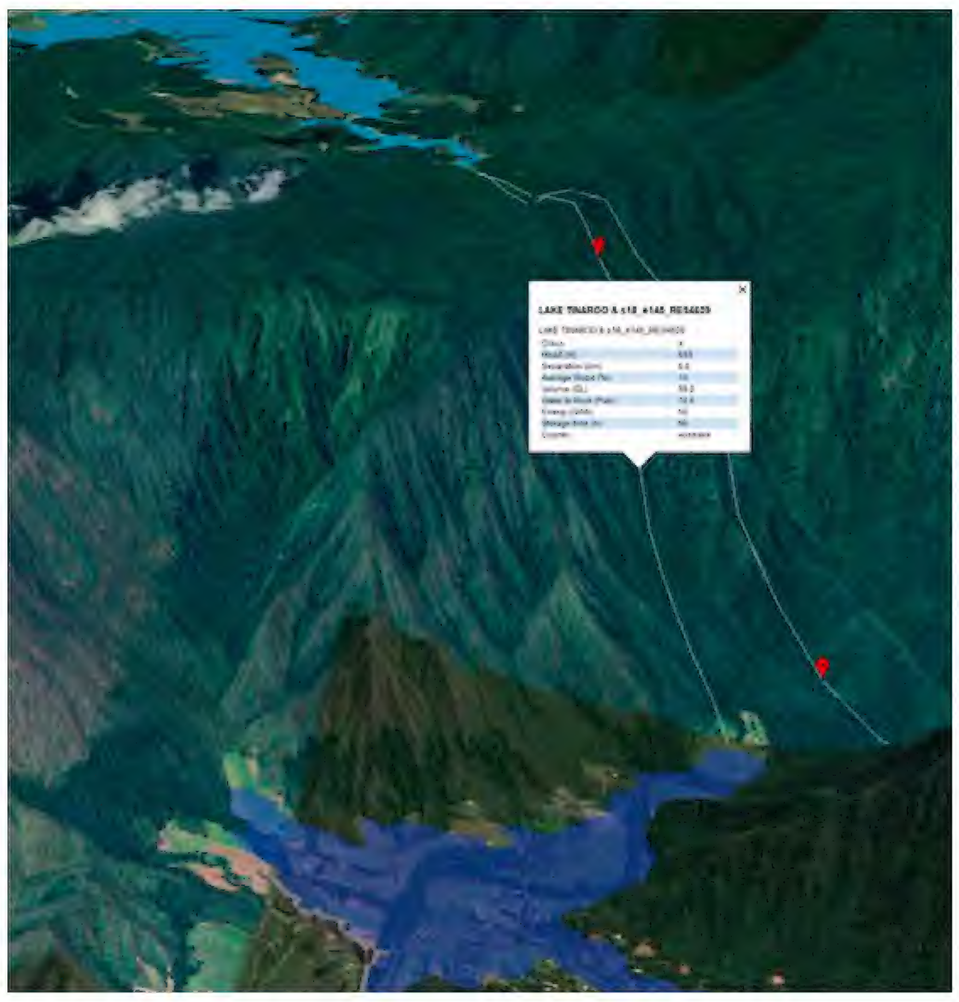

Figure 4: Class A 50 GWh site at Tinaroo near Cairns with information popup

Queensland: Teemburra, Eungella, Borumba, Cressbrook, Tinaroo (Fig. 4) and others support Queensland's vast solar and wind energy potential.

WA: Harvey, Brockman and Dandalup reservoirs near Perth can support Western Australia's transition to renewable energy. However, PHES sites in the west are not nearly so good or plentiful as in the east.

Figure 5: Tasmania has many options

Tasmania: has dozens of excellent options (Fig. 5).

Conclusion

All of these sites and many more can be browsed by users, and detailed information for each site is available at the click of a button.

Acknowledgements

The Australian Renewable Energy Agency financially supported development of both the Blue and Greenfield Atlases. Matthew Stocks contributed substantially to this work.

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Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, pp. 202–209. ISSN 0035-9173/22/020202-08

Australian seashores

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Introduction

Australian Seashores is an historic photograph exhibition at the University of Sydney's Chau Chak Wing Museum (2022–2023). It celebrates the landmark text of the same name, which was first published in 1952 by Professor William J Dakin and Isobel Bennett of the University of Sydney, with Elizabeth Carrington Pope of the Australian Museum. The book was aimed at a broad audience, from general enthusiast to academics, and richly illustrated with original photographs. The exhibition uses the images to celebrate the writers, the book, and their impact on Australian marine science. It also considers potential new roles for the photographs, particularly in documenting environmental change over the past 70 years.

Australian Seashores: The book

Australian Seashores is a classic textbook, reprinted and revised over a 35-year period from 1952 to 1987. Its concentration on Australian environments and organisms was a major departure from the essentially European and laboratory-based textbooks previously available to Australian students. Through *Australian Seashores*, Dakin, Bennett and Pope trained generations of marine scientists and educated the Australian public about local seashores. The subtitle "A guide for the beach-lover, the naturalist, the shore fisherman and the student", reveals the broad audience they aimed to reach.

(Fig. 1 HP84.7.110.57) Isobel Bennett (right) and ?Elizabeth Pope examining a log covered in gooseneck barnacles, Gerroa, NSW. (See Plate 99)

Covering an array of topics (from how different coastlines are formed and change, to why the sea is a particular colour, to an outline for identifying the main plant and animal groups found on Australian seashores and their biology), the authors also laid the foundation for "citizen science" of our era. The book grew initially from scientific surveys of New South Wales intertidal ecosystems published in 1948 by Dakin, Bennett and Pope (Fig. 1). What resulted was not just a textbook for armchair reading, but an invitation for Australians to identify as coastal dwellers and turn their gaze from the interior of the country to the coast.

Despite its title, the geographic scope of *Australian Seashores* is restricted mostly to the New South Wales coastline. Organised into chapters of the main animal groups, the book is also restricted to the plants and animals that occupy the narrow part of the

(Fig. 2 HP84.7.16.5) The brown algae *Splachnidium rugosum* (Linn.) Greville, 1830. (See Plate 16)

shore that is covered and uncovered by the changing tides, the "intertidal zone." This is an area of high biodiversity, but at the time of publication was poorly understood, even though it was easily accessible. Black and white photographs and illustrations were included to help the reader identify a variety of plant and animal species (Fig. 2, Fig. 3), which were organised into chapters of related species of commonly found groups. The coverage of common animals was so comprehensive that the book continues to serve as a useful identification guide today.

Australian Seashores: The exhibition

The Chau Chak Wing Museum at the University of Sydney incorporates the former Macleay Museum, Nicholson Museum and University Art Collection. The *Australian Seashores* exhibition opened in August 2022

(Fig. 3, HP84.7.41.1) The horned ghost crab, *Ocypode ceratophthalma* (Pallas, 1772), photo by Gwen Burns. (See Plate 41)

and will run until the end of March 2023. It is the third exhibition within the dedicated historic photographic gallery of the Museum, which opened in November 2020. Curated by Anthony Gill with Kelsey McMorrow, it is the first to focus on a scientific subject area. The exhibition celebrates the book and its authors, and the role they played in influencing and inspiring Australian marine science.

The exhibition features enlarged and original photographs, field notes (Fig. 4) and ephemera, natural history specimens, Dakin's Leitz microscope used by Isobel Bennett, and copies of the book. It is arranged in the following sections: the seashore, the authors and fieldwork, plants, animals, fisheries and plankton, and citizen science.

One species in particular, the snapping shrimp, *Alphaeus strenuous* Dana, 1852, is focussed on to show the place of Dakin, Pope and Bennett's research in our modern understanding of the species. At the time of the book's publication, the question of how the shrimp made their snapping sound was a matter of debate. The authors put forward that the sound was produced by the small part of the claw clicking back into a socket

(Fig. 4, HP85.44.21) Field notebook belonging to Elizabeth Pope from a trip to Eden in 1946.

in the main part of the claw and creating a jet of water. While this is mostly correct, it has been recently discovered that the jet of water is so fast that it cavitates, forming a vapour bubble. The snapping sound, in fact, results from the bubble collapsing (Versluis et al. 2000).

The collaborative leadership of women scientists involved in the research and writing of *Australian Seashores* is a strong theme of the exhibition. Another theme, taken from the book's encouragement of all Australians to understand and enjoy the science of the seashore is on citizen science. Many of the images taken during the making of the book show features of the coast that now have changed significantly. The exhibition included an area inviting today's citizen

(Fig. 5, HP84.7.7.1) Waves breaking in shallow water. Warriewood, Sydney. (Plate 7)

scientists to document the geology, flora and fauna of Australia's coasts and to post images of what they see from flourishing plastics to details of catch-sizes, frequency and counts of molluscs and the arrivals of exotic or seldom seen species brought to the coast with changing temperatures and salinity.

(Fig. 6, HP84.7.73.1) Oyster-spat collecting beds on the Hawkesbury River. (Plate 73)

For the final section of the exhibition, on citizen science, today's beachgoers are invited to continue to document and share their observations of our seashores. Comparisons between contemporary photographs and those taken for *Australian Seashores* can contribute to our understanding of how the environment has changed over the past 70 years and may also reveal new areas for scientific research. For instance, comparing Fig. 5 to the same landscape today, reveals vegetation of the sand dunes, as well as increased urban development. Fig. 6 reveals both continuity and change — although oyster spats are still found on the Hawkesbury River, steam trains have since been replaced.

Australian Seashores: The authors

William John Dakin (1883–1950) was born in Liverpool, UK, and held academic positions in Europe and Western Australia before serving as Professor of Zoology at the University of Sydney from 1929 to 1947. His research interests were very broad, but his passion was for the sea and marine biology. He was also a dedicated public educator, a pioneering science communicator on ABC radio, and instrumental in revising the secondary school science curriculum. Dakin drew upon his knowledge of the natural world when he was seconded to the Department of Home Security to develop camouflage strategies during World War Two. Dakin's wife Gladys (née Lewis) was also a trained zoologist, and frequently served as his research and field assistant (Fig. 7).

(Fig. 7, HP84.7.120.07) The plankton net being deployed from the University research yacht *Thistle*. Isobel Bennett can be seen second on the left, and Gladys Dakin on the right.

When published shortly after his death, Dakin was listed as sole author of *Australian Seashores*, but the book was a collaboration with his research assistant Isobel Bennett and former student Elizabeth Pope. Together, Bennett and Pope also took on much of the fieldwork when Dakin's health was in decline and saw through the book's publication after his death.

(Fig. 8, HP84.7.110.29) Isobel Bennett holding a shucking knife while inspecting barnacles on a rock platform at Freshwater, Sydney. (Plate 3)

Isobel Bennett (1909–2008) was a pioneer in Australian marine biology and remains an inspiration to generations of marine scientists (Fig. 8). She was initially hired to research historical records for Dakin's 1938 *Whalemen Adventurers*, but later assisted Dakin with his research (1933, 1940) on Australian plankton, intertidal organisms, and camouflage. Bennett took on the immense responsibility of revising and editing subsequent editions of *Australian Seashores*, updating information, species identifications and eventually replacing all of the original black and white photographs with colour ones. She also wrote eight other influential books. She received widespread recognition for her work, including the first Honorary Master of Science from the University of Sydney in 1962, a Mueller Medal from the Australasian Association for the Advancement of Science in 1982, and an Honorary Doctor of Science

from the University of New South Wales in 1995.She was made an Officer of the Order of Australia for her services to marine biology in 1984.

Elizabeth Pope (1912–1993) was a trailblazer and inspirational Australian marine biologist. Her University of Sydney master's thesis on the ecology of intertidal organisms at Long Reef, Sydney, was inspiration for the wider survey of New South Wales intertidal zones that led to *Australian Seashores*. Pope was initially employed as a scientific assistant at the Australian Museum in 1939, becoming inaugural curator of the Worms and Echinoderms Department in 1957, and Deputy Director of the museum in 1971. Her research focused on the taxonomy and ecology of marine invertebrates (Fig. 9). Among her contributions in science communication were regular appearances on ABC Radio's *The Argonauts* and her 1958 book with Patricia McDonald, *Exploring Between Tidemarks*.

(Fig. 9, HP84.7.26.1) A sea pen, *Cavernularia obesa* Valenciennes (Milne Edwards & Haime, 1851).

Australian Seashores: The collection

Materials relating to the production of *Australian Seashores*, including photographs, typed drafts, research notes and specimens, are spread across several institutions. Isobel Bennett's notes and images are largely held by the National Library of Australia and Elizabeth Pope's archive within the Australian Museum. Various family members also have memorabilia and materials relating to one of the authors. The University of Sydney Archives holds some papers relating to Dakin, while the Macleay Historic Photography collection at the Chau Chak Wing Museum holds two Dakin/book-related collections.

(Fig. 10, HP84.7.32.3) A southern feather duster worm, *Sabellastarte australiensis* (Haswell, 1884).

The first collection of these, donated by the Dakin family in the early 1980s, reflects Dakin's extensive research of marine biology, as well as his work in the University's Zoology Department. It comprises glass and film negatives, photographic prints, and some ephemera. Most of the collection relates to material used for the 99 plates and

(Fig. 11, HP84.7.37.5) The Greentail prawn, *Metapenaeus bennettae* Racek & Dall, 1965. (See Plate 37)

(Fig. 12, HP84.7.110.32-34) A page from a ring binder. Top left inscribed 'IB', note Bennett's camera, top right inscribed 'EP pickie Dakin with Leica'.

figures in *Australian Seashores*. There are also photographic prints of marine invertebrates and seaweeds, and many views of NSW coastal landscapes. The second smaller collection consists of Pope's field and research notes, faunal lists, photographic prints and ephemera — including poems written by the researchers and their friends during their fieldwork expeditions for *Australian Seashores*. It is from these two collections that the *Australian Seashores* exhibition is drawn.

Although all three authors were involved in the publication's photography, individual images are not credited, save for those by the Zoological Department's photography assistant Gwen Burns, who took many of the microscopic and other laboratory-based images (Fig. 10). These images also reveal her photographic techniques and record details of shutter speeds and dates (Fig. 11). One invaluable group of photographic prints are those included in a ring-binder folder, with photographic prints mounted on card. In this group, notes on the subjects are occasionally included and the multiple photographers involved in the research are documented (Fig. 12).

The materials in the Dakin collection also give some insight into the production of the book: marginalia on glass negatives hint at the large number of photographs taken for each published photo (Fig. 13); uncropped images reveal staging associated with photographs (Fig. 14); field and research notes suggest at the immense amount of effort that went into gathering information and images; poetry written on fieldtrips offer insight into the comradery of the participants. These various kinds of images were included in the exhibition to give a sense of the social aspects of their careful and painstaking research and to show how their findings were used within the book itself (Fig. 15).

(Fig. 13, HP84.7.11.1 A 35-mm proof strip with William Dakin (or possibly his son William Peter Harvey) examining zonation pattern on a rocky shore. (See Plate 11)

(Fig. 14, HP84.7.9.3) Hand-coloured glass negative of Phyllosoma larva of a spiny lobster. (See Plate 9, a combined plate of images of planktonic animals)

(Fig. 15, HP84.7.99.2) Coaxing silver gulls (*Chroicocephalus novaehollanidae* (Stephens, 1826)) into position for a photograph at Long Reef, Sydney, NSW. (See Plate 99)

Conclusions

Preparation of exhibitions such as *Australian Seashores* provide opportunities for more general curation of the collections on which they are based. Moreover, audience feedback can provide novel information not otherwise available in museum records. Many responses to the exhibition have acknowledged how important the book was to individuals, and how it still occupies pride of place in private libraries. Other responders were former students who came under the influence of one or other of the authors, recalling how they were inspired or guided to eventual careers in science. Two particularly important responses were from family members of Bennett and Dakin who spent time in the exhibition not only recounting stories, but also helped identify people and places in depicted in the Dakin collection photographs. Responses such as these are critical for improving our understanding of collections and putting them into proper context.

Acknowledgments

Mostly taken between 1930–1948, all the photographs reproduced here from the Chau Chak Wing collection can be found on-line using the unique "HP" number in the caption. Plate numbers in the captions refer to the 1952 edition of *Australian Seashores*.

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Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, p. 210. ISSN 0035-9173/22/020210-02

Thesis abstract

The intersection of nitrosative stress, ferroptosis and aberrant calcium signalling in Alzheimer's disease

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Abstract of a thesis for a Doctorate of Philosophy submitted to The University of Wollongong, Wollongong, Australia

Alzheimer's disease (AD) is the most common neurodegenerative disorder characterised by the deposition of two protein aggregates, amyloid β and hyperphosphorylated tau, in conjunction with the breakdown of neuronal signalling pathways and cell death. It has been proposed that disruption to calcium signalling may be a central neurodegenerative mechanism driving AD, with several distinct pathogenic pathways contributing to the presentation of aberrant signalling phenotypes. Unfortunately, over 30 years of clinical trials targeting the removal of the protein aggregates have largely failed, however, short-term symptomatic relief has been observed when modulating signalling pathways. This highlights the need to further understand the pathophysiology of neuronal signalling during AD.

To address this knowledge gap, it was hypothesised that nitrosative stress and ferroptosis, two discrete pathogenic pathways implicated with AD, would alter calcium signalling dynamics. Nitrosative stress, the consequence of aberrant levels of the second messenger nitric oxide (NO), was examined due to the intricate relationship between NO production and glutamatergic calcium signalling. Ferroptosis, a cell death pathway associated with redox dyshomeostasis, was assessed due to its disruption of lipid membranes where calcium signalling receptors and channels are localised. To investigate this hypothesis, induced pluripotent stem cell (iPSC) derived neurons generated from AD donors were used as an *in vitro* model to understand if, and how, these alternative disease mechanisms may underlie the presentation of dysfunctional calcium signalling phenotypes.

Live cell calcium imaging demonstrated a complex dysfunctional calcium signalling phenotype in AD neurons, which consisted of fast spontaneous calcium transients in addition to reduced but prolonged glutamatergic calcium responses, a higher proportion of non-responsive neurons, and elevated intracellular calcium levels, when compared to the control neurons. This demonstrates the recapitulation of several distinct calcium phenotypes hypothesised to contribute to AD pathogenesis, representing the establishment of a humanised *in vitro* disease system to investigate mechanisms of AD.

Western blot quantification of the calcium activated enzyme responsible for producing NO, neuronal nitric oxide synthase (nNOS), demonstrated it was significantly increased in brain regions implicated with AD and iPSC-derived neurons from AD donors. Inhibition of nNOS activity, or scavenging of endogenous NO, decreased

the proportion of spontaneously signalling AD neurons, while significantly decreasing the glutamatergic calcium response in healthy neurons, in contrast to AD neurons, where this modulatory effect was lost. This suggests pathogenic modification of signalling receptors under conditions of elevated NO, implicating nitrosative stress in the presentation of aberrant calcium signalling phenotypes.

Evidence suggested that AD neurons had an increased susceptibility to nitrosative/oxidative stress damage, with an altered distribution of the lipid soluble antioxidant α-tocopherol (α-toc), and decreased levels of the antioxidant enzyme, glutathione peroxidase. This decreased resilience to redox dyshomeostasis likely increased neuronal vulnerability to the lipid peroxidation cell death pathway, ferroptosis. Induction of ferroptosis significantly reduced cell viability and the amount of phosphatidylethanolamine polyunsaturated fatty acid lipid species, in addition to abolishing glutamatergic calcium signalling. Supplementation with α-toc reduced the proportion of spontaneously signalling neurons and partially protected against the loss of select fatty acid species, implicating nitrosative/oxidative stress damage and alterations to the lipid membrane in the breakdown of neuronal calcium signalling.

Overall, the work presented in this thesis shows how the AD pathogenic alterations, nitrosative stress and ferroptosis, contribute to the presentation of calcium signalling phenotypes during AD. Identifying and understanding how different disease pathways modify neuronal calcium signalling is critical as effective treatments will likely need to target several mechanisms to ensure robust efficacy and minimise the contribution of alternative disease pathways that would continue to drive pathology.

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Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, p. 212. ISSN 0035-9173/22/020212-01

Thesis abstract

Deference and intervention in the characterisation of work contracts

Pauline Bomball

Abstract of a thesis for a Doctorate of Philosophy submitted to the Australian National University

This thesis examines judicial approaches to the characterisation of work contracts in Australia. Important consequences flow from the characterisation of a contract as one of employment. A significant number of labour statutes bestow rights and protections upon employees only, thereby excluding other types of workers, such as independent contractors, from their coverage. Employing entities seeking to avoid statutory labour obligations use various contractual techniques to disguise employees as independent contractors. In some cases, courts have afforded deference to these contractual arrangements. In other cases, courts have adopted an interventionist approach, disregarding or according limited weight to the terms of the written contract, and focusing instead on the underlying substance of the relationship. There is, however, an absence of clarity as to the conceptual and doctrinal justifications for such intervention, resulting in judicial oscillations between deference and intervention.

This thesis argues that Australian courts should adopt the interventionist approach to the characterisation of work contracts. It presents the conceptual and doctrinal justifications for the interventionist approach and constructs a two-stage analytical framework for the application of this approach by the courts. In the course of elucidating and defending the interventionist approach to characterisation, this thesis addresses broader conceptual questions concerning the distinction between formalism and substantivism in common law adjudication, the interaction of common law and statute, and the normative tensions that arise when the norms of public regulation are channelled through the vehicle of private law. The thesis focuses primarily on Australian law, though it also draws upon the law of the United Kingdom, United States and Canada, where relevant.

The increasing diversity of work arrangements in the modern economy, fuelled in part by the emergence of the gig economy in recent years, has placed strains upon the common law's architecture for identifying the beneficiary of labour law's protections. This thesis seeks to make a contribution to the important task of reconstructing that architecture and consolidating its conceptual and doctrinal foundations. The thesis takes the form of a thesis by compilation, comprising an integrative chapter and seven sole-authored peer-reviewed journal articles.

(Dr Bomball was awarded the 2022 ANU J.G. Crawford Prize for HASS.)

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Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, p. 213. ISSN 0035-9173/22/020213-02

Thesis abstract

Risk factors for running-related pain after childbirth

Shefali Christopher

Abstract of a thesis for a Doctorate of Philosophy in Physiotherapy submitted to The University of Newcastle, Callaghan, Australia

Background: Women are initiating or returning to running for exercise after childbirth while also recovering from a myriad of perinatal changes to the body. For these women, integration into a high impact sport is not easy; up to 35% of postpartum runners report painful running. While there are established evidence-based rehabilitation protocols for returning to sport after a major injury, such evidence does not exist for the postpartum running population. This is likely due to a lack of evidence on possible musculoskeletal risk factors associated with running-related pain in postpartum women. A baseline understanding of potential risk factors for running-related pain in postpartum runners is needed to provide a starting point for future validation and interventional studies.

Purpose: The overall aim of this thesis is to identify possible risk factors for running-related pain in postpartum runners and determine their relationship to running, postpartum variables, and movement kinematics.

Methods: Because information on risk factors for running-related musculoskeletal injury in postpartum runners was non-existent, a systematic review was initially performed to understand the relationship between running injury and musculoskeletal strength, flexibility, range of motion and alignment alterations. A separate systematic review was also conducted to understand the risk factors associated with first-onset lumbopelvic pain (the most common type of pain) in postpartum women. A Delphi study was performed to gain expert consensus on musculoskeletal impairments and running-related risk factors observed in postpartum runners. The information gathered from these studies was used to design and conduct a survey of postpartum runners with and without running-related pain to explore the relationship between demographic, postpartum and running-related risk factors, and pain. Since the effects of postpartum musculoskeletal changes on running are unknown, a laboratory study determined kinematic and musculoskeletal differences between postpartum runners and nulliparous controls.

Results: Both systematic reviews found low-quality evidence and bias within the studies reviewed. Seven studies found seven clinical assessments that predict running-related pain: hip strength; range of motion; flexibility; alignment; knee strength; and ankle alignment. Four studies identified five risk factors associated with first-onset postpartum lumbopelvic pain: C-section with epidural anesthesia; length of first stage labour; race; age; and urinary tract infections. The 45 experts in the Delphi study reached consensus on the following risk factors observed in postpartum

runners: abdominal, hip, and pelvic floor weakness; hip extension restriction; anterior pelvic tilt; general hypermobility; laxity in the abdominal wall; tightness in hip flexors, lumbar extensors, iliotibial band and hamstrings; a Trendelenburg sign; dynamic knee valgus; lumbar lordosis; over-pronation; and thoracic kyphosis. The survey of 538 postpartum runners found six variables that increased the odds of postpartum running-related pain: runner type-novice; postpartum accumulated fatigue scale score; previous running injury; most recent delivery-vaginal; incontinence; and amount of sleep. Using these variables, a clinical tool was created that indicated a 62% probability of having postpartum running-related pain if 4 of 6 variables were present. The laboratory study concluded that postpartum runners had 24.3% greater braking loading rate (mean difference (MD): 3.41 NBW/s; 95% CI 0.08, 6.74), 14% less hamstring flexibility (MD:10.98°; 0.97, 20.99), 25.9% less hip abduction (MD: 0.04 NBW, 95% CI 0.00, 0.08), and 51.6% less hip adduction strength (MD: 0.06 NBW; 0.02, 0.10) than controls.

Conclusions: This thesis established the first steps in identifying running-related risk factors in postpartum runners. This baseline understanding of potential risk factors for running related pain provides a starting point for prospective studies to investigate risk factors for the onset of running-related pain in postpartum runners. It can also assist health care. providers educate postpartum runners and develop interventions to assist postpartum women to stay injury free as they initiate or return to running.

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Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, p. 215. ISSN 0035-9173/22/020215-02

Thesis abstract

The structure and kinematics of the Magellanic stellar periphery

Lara Rose Cullinane

Abstract of a thesis for a Doctorate of Philosophy submitted to the Australian National University

The Large and Small Magellanic Clouds (LMC/SMC) are of fundamental importance in near-field cosmology. As the closest pair of interacting dwarf galaxies, they constitute the prototype system for studying the influence of tidal interactions on galaxy evolution. However, the orbital and interaction history of the Clouds — critical to understanding these influences — remains relatively unconstrained.

This thesis aims to understand the effects of past interactions between the Magellanic Clouds by performing the first dedicated kinematic study of the Magellanic stellar outskirts. Stars in these regions are strongly susceptible to external perturbations, and the resulting structural and kinematic signatures are persistent: evidenced by a wealth of substructure observed across the Magellanic periphery. To kinematically study these structures, I have developed and led the Magellanic Edges Survey (MagES), a spectroscopic study using the 2dF+AAOmega instrument on the Anglo-Australian Telescope, targeting ~8700 red clump and red giant branch stars across the periphery of the Clouds. In combination with astrometric measurements and high-precision photometry from the Gaia satellite, the survey provides 3D kinematics and abundance information critical for understanding the effects of dynamical perturbations on the Magellanic system.

As a first demonstration of the efficacy of MagES data, the kinematics of two fields in the northern LMC disk are investigated. These are found to exhibit relatively undisturbed disk-like kinematics, enabling calculation of the most distant direct mass estimate for the LMC.

Focus is then directed to a large arm-like substructure to the north of the LMC. This structure is determined to be made from disturbed LMC disk material, with its discrepant kinematics relative to the disk indicative that it was strongly perturbed during a recent interaction with the Milky Way. Comparison with dynamical models reveals the feature has not been closely influenced by close passages or disk crossings of the SMC around the LMC within the past Gyr, but earlier SMC passages may have contributed to its formation. These are the first kinematic constraints on the dynamical history of the Clouds prior to their most recent pericentric passage ~150 Myr ago.

Finally, the kinematic and structural properties of the outer LMC at galactocentric radii beyond 10 degrees are explored. The north-eastern LMC disk is remarkably undisturbed, with geometry and kinematics near-identical to those at smaller radii. In contrast, the western and southern LMC disk are highly disturbed, with deviations exceeding 25 km/s from equilibrium disk kinematics, and significantly elevated veloc-

ity dispersions. Red clump stars in these regions are also significantly brighter than expected for an undisturbed disk, indicating substantial warping. It is further demonstrated that several substructures to the south of the LMC, including two claw-like features and a long arm-like structure extending around the south-eastern disk, comprising predominantly LMC material — as opposed to SMC debris — but display strongly disturbed kinematics. Comparisons with dynamical models reveal the western LMC disk is likely significantly affected by an SMC crossing of the LMC disk plane ~400 Myr ago. However, southern substructures appear considerably more complex than observed in any models, plausibly requiring multiple previous interactions with the SMC to fully explain their observed dynamical properties.

In summary, the MagES data presented in this thesis provide a set of unprecedented empirical constraints on the interaction history of the Clouds that will be critical for guiding future numerical models aiming to accurately describe the complex evolution of the Magellanic system.

(Dr Cullinane was awarded the 2022 ANU J.G. Crawford Prize for STEM.)

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Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, p. 217. ISSN 0035-9173/22/020217-03

Thesis abstract

Examining the role of auditor-audit firm and auditor-client relationships on auditors' professional skepticism

Aeson Luiz Dela Cruz

A thesis submitted to Macquarie University in fulfillment of the requirement for the degree of Doctor of Philosophy

Professional skepticism (PS), which is regarded as one of the most important responsibilities in the audit profession and a "critical attribute of auditor performance" (Nelson, 2009, p.5), has been increasingly emphasized by regulators, standard setters, professional bodies, and researchers. However, prior research has not paid adequate attention to the role of the relationships between auditors and various participants within the audit process — such as their firms and their clients — in driving PS. While these relationships within the audit context have the potential to generate attitudinal and behavioural outcomes that are advantageous to audit firms, and can build on their existing initiatives to enhance audit quality, they have not been adequately examined. Therefore, this thesis contributes to the literature by examining aspects of the auditor-audit firm and auditor-client relationship along with the mechanisms through which these relationships impact auditors' PS in the Philippines. The Philippines is an appropriate national context for the thesis since it has fully adopted the International Standards on Auditing (ISAs) upon which pronouncements on PS are largely based. Findings from the thesis's theoretical models in the Philippine setting may be extrapolated for many other countries that have adopted the ISAs. Additionally, regulatory bodies such as the Public Company Accounting Oversight Board (PCAOB) have expressed persistent concerns over the lack of PS in the Philippines. While all countries face challenges in ensuring and enhancing PS, the choice of the Philippine context is particularly apposite as a site where issues of audit quality and PS have been identified. Importantly, the prevalence of such issues on financial reporting and audit quality in the Philippines provides an appropriate "test bed" for examining factors that may affect PS. This thesis adopts an interdisciplinary approach by drawing on the literature and theoretical perspectives on social psychology, organizational behaviour, and service science to provide an in-depth understanding of the psychological mechanisms through which auditor-audit firm and auditor-client relationships operate to drive PS. The aim of this thesis is attained through three empirical papers utilizing quantitative (Papers 1 and 2) and qualitative (Paper 3) research designs.

The first paper extends the literature by developing and testing a theoretical model that examines perceived organizational support (POS) as a focal predictor of auditors' intentions to engage in skeptical action. This paper also examines organizational identification as a relevant psychological mechanism through which POS affects

auditors' PS. Specifically, this paper argues that organizational identification mediates the relationship between auditors' POS and their intentions to engage in skeptical action. Moreover, this paper also develops alternative hypotheses to examine whether firm type moderates the link between POS, organizational identification, and intentions to engage in skeptical action. The paper's theoretical model was tested in a survey involving 198 auditors in the Philippines. The findings show that organizational identification mediates the relationship between POS and auditors' intentions to engage in skeptical action. The study also found that the conditional indirect effect of POS on auditors' intentions to engage in skeptical action via organizational identification is stronger for non-Big 4 firms compared to Big 4 firms. The results highlight the importance of providing a supportive environment to encourage auditors to form intentions to engage in skeptical action.

The second paper contributes to the literature by developing a theoretical model that examines the auditor-audit firm relationship from a psychological contract perspective. Specifically, this paper examines how ideological psychological contract (IPC) fulfillment is associated with auditors' intentions to engage in skeptical actions and organizational citizenship behaviour (OCB). This paper hypothesizes that work meaningfulness mediates the relationships between IPC fulfillment and auditors' intentions to engage in skeptical actions, and between IPC fulfillment and OCB. This paper's theoretical model was tested by conducting a two-wave online survey involving 250 auditors in the Philippines, and after which, both an *ex-ante* procedural remedy and an *ex-post* test were performed to mitigate common method bias. Findings show that IPC fulfillment reinforces auditors' perceived work meaningfulness, which then motivates them to form greater intentions to engage in skeptical actions and OCB. By invoking psychological contract theory, this paper provides additional insights into how auditor-audit firm relationships anchored on ideologies reinforce aspects of auditor performance that can contribute to firms' audit quality initiatives.

The third paper contributes to the literature by examining audit engagements from a co-production perspective. This study analysed interviews of 24 audit partners and 26 CFOs and controllers to ascertain whether auditors and audit clients view the audit as a co-production and if so, how do these impact PS. Moreover, it also mobilized Knechel et al., (2020)'s thesis that an audit is a professional service, and social exchange theory (SET) to answer the study's research questions. Findings show that auditors and clients perceive that they co-produce audits as they each contribute resources and competencies that are combined at each stage of the audit. The results demonstrate that co-production is facilitated by relationships that are characterized by reciprocity and trust between auditors and clients. The study also found that a shared notion of audits as co-production helps overcome information asymmetries, which then enables auditors to exercise PS. Nonetheless, the study also found evidence to support Knechel et al., (2020)'s proposition that there is a "fine line that separates participating in a collaborative network" that may facilitate skeptical judgments and actions, from "abdicating professional responsibilities" that result in impaired PS.

Findings from this thesis provide additional insights into existing theoretical PS models. Most theoretical frameworks such as those of Hurtt et al. (2013) and Nolder & Kadous (2018) operationalize organizational factors influencing PS via specific aspects of audit firm culture. This thesis complements these models by demonstrating the relevance of examining aspects of the auditor-audit firm and auditor-client relationships as factors affecting PS. This thesis further advances existing theoretical PS models by mobilizing unique theoretical perspectives in examining the underlying psychological mechanisms that link situational factors and skeptical behaviour. This thesis demonstrates the importance of unpacking these relevant mechanisms to provide additional insights into *how* situational factors are linked to auditors' PS. Moreover, findings of this thesis which are based on auditors' and clients' perceptions anchored in their actual experiences, provide opportunities for audit researchers to use latent variables to capture aspects of the audit firm environment and auditor-client relationship to better understand their role in enhancing skeptical behaviour. Lastly, this thesis also provides practical implications for global audit firms and their networks, regulators, and standard setters consistent with their initiatives to improve PS and strengthen audit quality.

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Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, p. 220. ISSN 0035-9173/22/020220-01

Thesis abstract

Modelling neuronal excitability changes in ALS using iPSC-derived motor neurons and astrocytes

Dzung Phuong Do-Ha

Abstract of a thesis for a Doctorate of Philosophy submitted to the University of Wollongong, Australia

Amyotrophic Lateral Sclerosis (ALS) is the most severe form of Motor Neurone Disease. This fatal neurodegenerative disease causes the deterioration of the motor system leading to progressive paralysis. One of the earliest clinical observations in ALS patients is hyperexcitability of motor neurons in the motor cortex and spinal cord, prior to hypoexcitability and deterioration of motor function. The overarching objective of this thesis was to use induced pluripotent stem cells (iPSCs) from ALS patients to investigate electrophysiological changes to motor neurons, which may impact ALS progression. Firstly, the differentiation conditions of iPSC-derived motor neurons were optimised to improve the yield of electrophysiologically active motor neurons. Whole-cell patch clamping revealed that neuronal Na^+ and K^+ currents increased by more than 3-fold with the optimised culture conditions. Moreover, the proportion of repetitively firing neurons increased from less than 5% to approximately 75%. Secondly, using these improved culture conditions, the electrophysiological properties of *CCNF*^{S621G} motor neurons were compared to CRISPR/Cas 9 generated isogenic control cell lines. The *CCNF*^{S621G} motor neurons showed 3-fold increase in repetitively firing neurons compared to control motor neurons. This was further accompanied with a significant increase in Na^+ and K^+ currents. Together this suggests that the *CCNF*^{S621G} mutation alters the electrophysiological properties of motor neurons leading to neuronal hyperexcitability. Finally, iPSC-derived motor neuron and astrocyte co-cultures were used to investigate the effect of ALS astrocytes on motor neuron excitability. ALS-derived astrocytes caused a loss of neuronal firing in both ALS and control motor neurons. Moreover, Na^+ and K^+ currents were reduced by up to 55% and 30%, respectively. Together these findings showed that the addition of ALS astrocytes induced hypoexcitability in ALS, as well as control motor neurons. This suggests that ALS astrocytes could be involved in the transition from motor neuron hyperexcitability to hypoexcitability.

Overall the work presented in this thesis showed that the *CCNF*^{S621G} mutation causes hyperexcitability in iPSC-derived motor neurons. However, this hyperexcitability phenotype was lost in the presence of ALS astrocytes. Thus, this work highlights that the cellular crosstalk between motor neurons and astrocytes plays a significant role in altering intrinsic neuronal excitability, which could impact ALS progression.

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Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, p. 221. ISSN 0035-9173/22/020221-02

Thesis abstract

Investigation of occupant behaviour in residential buildings

Bongchan Jeong

A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy at the University of Sydney

The present research seeks to characterise occupant behaviours in a residential setting to improve the predictive skill of residential energy simulation models. To date only a handful of studies have been done in Australian residential environments because of the difficulty and cost of building up a large sample size. As a result it has been common to apply adaptive comfort models derived from office building studies in residential settings, despite the expectation that occupants in the latter context would have more adaptive opportunities compared to counterparts in office buildings, given that the degree of control over their environment in office environment is usually quite restricted.

The objective of this thesis is to establish an empirical basis to better understanding occupant behaviours and perception of comfort in the residential context. A longitudinal field observation campaign was conducted in 41 Australian homes in South-East Queensland across a one-year period (2019–21) that spans one summer, one swing season (spring or autumn), and one winter. A custom data acquisition system was developed and deployed in each participant's home to monitor the indoor environment and operations of ACs and windows. Additionally, an online comfort questionnaire was designed and administered to the sample householders via their smartphones throughout the survey period.

This study explores an alternative modelling approach that is capable of predicting diverse behavioural patterns. Statistical analysis was performed to predict occupant actions on AC operations (turning on/off) and window openings (opening/closing) in relation to outdoor and indoor environmental stimuli. The proposed model can be integrated into building simulation software to simulate the average operation pattern of AC and windows, as well as diverse patterns monitored amongst the participating households in the Australian residential context.

The study also examined the perception of thermal comfort and behavioural adaptation of residential occupants living in different climate zones of Australia. Data collected from a previous comfort study carried out in Sydney was utilised to make a comparison between the two different regions — Sydney: warm temperature (zone 5); and Brisbane: warm humid summer and mild winter (zone 2). The residents in the two regions registered different thermal sensations and thermal sensitivities. Probit analysis of TSV with room temperature was performed to define a range of acceptable temperature. The 80% acceptable temperature ranges for the two regions were 14.6–26.2°C in Sydney and 16.3–27.2°C in Brisbane, indicating that the acceptable

temperature range varied depending on the local climates.

Further analysis was performed on a large-scale time-use survey conducted at the national level from the Australian Bureau of Statistics (ABS) to assess occupancy and energy-related behaviours in Australian households. Profiles of occupancy state and energy-related activities were analysed for different seasons, day of the week, and household compositions. The activity sequences were further aggregated to reproduce the total time use for the activities and occupancy states.

The empirical findings from this study provide evidence-based behavioural models and simulation settings to be implemented in building energy performance simulation (BEPS) tools to more accurately predict indoor environmental conditions and energy consumption in residential buildings.

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Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, p. 223. ISSN 0035-9173/22/020223-02

Thesis abstract

Beauty ideals and body image among adolescent girls: a cross-cultural study

Vani Kakar

A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy, Macquarie University

While having an attractive appearance is valued globally, and body image concerns have been reported in most regions of the world where they have been studied, most research has been limited to individuals living in high-income, English-speaking nations. Such concerns are more pervasive among females than males, and are known to intensify during adolescence, which in turn, can have damaging consequences for one's physical and emotional well-being. To advance the cross-cultural scholarship within appearance research, this program of work examined beauty ideals, body image, and potential factors contributing to these constructs among adolescent girls living in diverse cultural contexts. The data for this research was obtained from a large-scale (n = 900) cross-sectional multinational survey of adolescent girls living in Australia (n = 184), China (n = 293), India (n = 223), and Iran (n = 200).

Part One of this thesis (Chapters Three and Four) examined beauty ideals and body image concerns with respect to a wide variety of facial and bodily attributes. Chapter 3 showed that despite being from socially, linguistically, religiously, and economically diverse backgrounds, girls' notions of beauty were largely similar and mirrored attributes of the Eurocentric-Western beauty ideal (e.g., curvaceously toned physique with straight/wavy hair). Slight contrasts in preferences were evident for non-weight related attributes which overlapped with girls' local beauty norms (e.g., fairness among Chinese and Iranians, and tanned ideal among Australians). Chapter 4 suggested that higher facial and bodily discrepancies were linked to lower appearance satisfaction, but this relationship appeared to be inconsistent across the four countries and was not moderated by the importance associated with those features. Further, girls in some countries (e.g., China and India) considered their facial attributes as more important than their bodily features to their overall appearance.

Part Two of this thesis (Chapters Five and Six) explored the potential role of different sociocultural factors in cultivating adolescents' beauty ideals and appearance concerns. Chapter Five investigated girls' perceptions of the extent to which different sources (e.g., peers, family, media), influenced their beauty ideals. While peers were perceived to be influential across countries, parents appeared to be more salient within India and Iran than in Australia, where social media influence rated the highest, and China who considered local celebrities as most powerful in shaping their beauty ideals. Chapter Six tested the applicability of the tripartite influence model of body image

and disordered eating for girls within each country and found support for a modified version incorporating direct effects from sociocultural influences on appearance satisfaction. Moreover, thin-ideal internalization and appearance comparisons mediated the link between sociocultural pressures and appearance concerns in all countries. Lastly, the salience of appearance-based pressures varied cross-culturally (e.g., family pressures in Iran and India and media pressures in Australia).

Together, while these findings highlight many similarities in appearance-based attitudes and related concerns between adolescent girls from quite disparate countries, they also identify specificities within each country that can guide preventative efforts to reduce the negative impact associated with poor body image for adolescent girls in these countries.

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Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, p. 225. ISSN 0035-9173/22/020225-04

Thesis abstract

Teacher-facilitated high-intensity interval-training intervention for older adolescents: evaluation of the Burn 2 Learn program

Angus Leahy

Abstract of a thesis for a Doctorate of Philosophy in Education submitted to The University of Newcastle, Callaghan, Australia

Background: Engaging in physical activity is associated with a plethora of health benefits for young people, with evidence suggesting that vigorous physical activity is particularly beneficial. Despite this, physical inactivity is a serious public health concern and is the fourth leading cause of death worldwide. Physical activity begins to decline during childhood and continues to decline with age, with behaviours established during this time tracking into adulthood. It is commonly agreed that schools have a unique platform to address this issue; however, previous school-based physical activity interventions have been relatively ineffective. Further, curriculum time dedicated to physical activity (i.e., physical education and school sport), is redirected towards other academic subjects (i.e., mathematics, science, and English) for students in their final years of schooling. This presents a clear challenge for researchers designing interventions targeting this age group. It also highlights the scope for novel approaches such as high-intensity interval training (HIIT) to be examined. Research examining the utility of school-based HIIT programs has gained traction in recent years; however, studies have been predominately conducted on a small scale. Further, while the physiological effects of this type of training have been well studied, the effects on mental health and cognition are relatively unknown.

Objective: The overarching aim of this thesis is to evaluate a school-based HIIT intervention for older adolescents. To do so, this thesis-by-publication presents a series of seven research papers, organised into three complementary yet distinct phases of research (Chapters 3–9). Chapters 3–9 are presented in order to reflect the following research progression: *scoping*, *feasibility and preliminary efficacy*, *effectiveness* (Figure 1.1).

Phase 1 — Scoping. Chapter 3: To systematically review and synthesise the effects of HIIT on cognitive and mental health outcomes in children and adolescents (Research aim 1). The physiological benefits of HIIT for adolescents are well established. Preliminary evidence also suggests that HIIT can improve young people's cognition and mental health; however, there has been no quantitative synthesis of the evidence. Therefore, a systematic search of six academic databases was conducted for experimental studies that examined the effects of HIIT on measures of cognitive function or mental health outcomes in children and adolescents. A total of 22 studies were included in the

review, of which 19 were included in the meta-analyses. Separate effects were conducted for acute and chronic studies, and for cognitive function (basic information processing and executive function), and mental health (well-being [affect], and ill-being) outcomes. For acute studies, a moderate effect was observed for executive function (ES = 0.50), while a small-to-moderate effect was found for affect (ES = 0.33) following HIIT. For chronic studies, HIIT resulted in a small overall effect for well-being (ES = 0.22), and small-to-moderate effects for executive function and ill-being (ES = 0.31 and 0.35, respectively). Although promising, due to the small number of studies included, and high heterogeneity, study findings should be interpreted with caution.

Phase 2 — Feasibility and preliminary efficacy. Chapter 4: To examine the feasibility and preliminary efficacy of a teacher-facilitated HIIT intervention for older adolescents (Research aim 2). Prior to its implementation in a large-scale effectiveness trial, the B2L intervention was pilot tested in two secondary schools in NSW, Australia. Specifically, this study evaluated the feasibility and preliminary efficacy in sample of older adolescents. Following baseline assessments, schools were randomised to receive a 14-week HIIT intervention (2–3 sessions/week) or instructed to continue regular practice (wait list control). Four domains of feasibility (recruitment, attendance, retention, and satisfaction) were assessed via process evaluation methods. A range of physical and mental health outcomes were also assessed at baseline and post-test. The intervention achieved high levels of recruitment and retention; however, adherence was lower than initially prescribed (1.9/week). Overall program satisfaction was high among both students and teachers (4.0/5). Significant effects were observed for cardiorespiratory fitness (8.9 laps) and mental health (–2.1 units), while no effects were found for muscular fitness or autonomous motivation. This study provided evidence for the feasibility of a teacher-facilitated HIIT intervention for older adolescents.

Chapter 5: To describe the feasibility requirements of administering a group-based cognitive test battery and examine the preliminary efficacy of a HIIT intervention on executive function (Research aim 3). Traditional assessments of executive function have limited utility in school-based research. Therefore, the aim of this study was to describe the feasibility requirements of administering a cognitive testing battery for older adolescents in the school setting. Participants completed a group-based testing battery assessing inhibition (flanker) and working memory (n-back) at baseline and 14 weeks following baseline assessments. Preliminary efficacy of a HIIT intervention and the associations between changes in fitness and changes in executive function were also examined. The testing battery was able to be conducted with up to six participants simultaneously, taking approximately 30 minutes to administer. Intra-class coefficient values demonstrated acceptable reliability among cognitive outcomes (ICC = 0.5–0.81), with significant changes in incongruent accuracy (flanker) and non-target accuracy (2-back). Regarding intervention effects, small-to-moderate effects (d = 0.15–0.37) were found for accuracy measures in favour of the intervention group, while several small associations were observed between changes in fitness and cognitive performance. Findings indicate that a group-based cognitive testing battery

is feasible to administer in a school setting. A larger and more representative sample is needed to confirm preliminary efficacy findings.

Phase 3 — Effectiveness. Chapter 6: To describe the rationale and study design for the B2L effectiveness cluster RCT (Research aim 4). This chapter describes the rationale and study protocol for the B2L effectiveness cluster RCT, which was conducted in 20 secondary schools from NSW, Australia. B2L is a 16-week school-based HIIT intervention for older adolescents in Year 11. This research paper details the study methodology of a cluster RCT, and extensively describes the intervention components and implementation strategies involved. Study outcomes include CRF (primary outcome), physical activity, muscular fitness, body composition, cognitive control, stress, psychological difficulties, autonomous motivation, psychological needs satisfaction, well-being, perceived fitness, HIIT self-efficacy, brain structure and function (sub sample) and on-task behaviour (sub sample). This study also describes a process evaluation to determine intervention fidelity. The results of this trial are presented in Chapter 9.

Chapter 7: To examine the effect of the B2L program on older adolescents' on-task behaviour and subjective vitality (Research aim 5). Physical activity has been linked with improvements in cognition and scholastic performance. In Australia, physical activity (i.e., physical education and school sport) is no longer a mandatory component of the curriculum for senior school students. There is evidence to suggest that a single bout of activity can alter young people's cognition, creating favourable learning conditions. Therefore, this study examined the acute effects of the B2L intervention on senior school students' on-task behaviour and subjective vitality. This was a sub-study of the B2L effectiveness trial, which included participants (n = 221) from 10 secondary schools located in NSW, Australia. For five weeks, teachers allocated to the intervention group facilitated the delivery of two high-intensity activity breaks per week during academic lessons. On-task behaviour was assessed using a momentary time sampling procedure, during a 30-minute observation period at baseline and post-test. Subjective vitality was assessed at the start and the end of the observed lesson during post-test only using a validated questionnaire. There was a significant effect on students' on-task behaviour (ES = 0.43), and subjective vitality (ES = 0.36) in favour of the intervention group. The results from this study highlight the potential scholastic benefits of providing students with opportunities to engage in physical activity during the senior school years.

Chapter 8: To examine the effect of the B2L program on older adolescents' physical, mental, and cognitive health (Research aim 6). The overarching focus of this thesis was to examine the feasibility, efficacy, and effectiveness of a school-based HIIT intervention for older adolescents. Previous school-based HIIT interventions have relied on research personnel to deliver physical activity session. While this approach is likely to lead to greater effects, it lacks scalability. To support the ongoing delivery of HIIT in schools, alternative approaches are needed. Therefore, this study evaluated the effectiveness of a teacher facilitated HIIT intervention, using a cluster randomised controlled trial design. A total of 670 older adolescents (16.0 [0.43] years) from 20 secondary schools located in NSW, Australia,

were assessed at baseline then randomised to the B2L intervention (10 schools, 337 participants) or a wait-list control (10 schools, 333 participants) group. Participants were reassessed at 6 months (primary end point) and 12 months post baseline assessments for a range of physiological, psychological, and cognitive outcomes. Effects were estimated using linear mixed models accounting for clustering at the individual and class levels. Significant effects were found for CRF, muscular fitness, physical activity, and hair cortisol concentration at 6 months. Several moderator effects were also observed. This study provided evidence for the effectiveness of a HIIT intervention for older adolescents. Importantly, the current study utilised a more feasible and sustainable delivery model than previous HIIT interventions.

Chapter 9: To describe the implementation process of the B2L program (Research aim 7). Schools are ideal settings to promote physical activity and fitness to adolescents; however, few studies have specifically targeted older adolescents. Further, relatively few school-based interventions have included comprehensive process evaluation. Therefore, the purpose of this research paper was to describe and evaluate the implementation of the B2L program, using data collected from the B2L effectiveness cluster RCT. The B2L program was delivered over three phases (Phases 1 and 2 [primary end-point], 6 months; Phase 3, 6 months) during a 12-month study period. Process evaluation data were collected from teachers (n = 22) and students (n = 333). Teachers reported facilitating the delivery of 2.0 (0.8) and 1.7 (0.6) sessions per week during Phase 1 and 2, respectively. Session delivery dropped to below one session per week during Phase 3. Researcher fidelity observations demonstrated that session quality was high; however, students' exercise intensity was lower than the prescribed target threshold of 85% age-predicted heart rate maximum. The B2L program was well accepted by both teachers and students, with over 80% of teachers reporting that they intended to deliver the program to a future student cohort, and approximately 70% of students intending to continue to participate in HIIT in the future. Findings from this study add to the scare process evaluation literature on the delivery of school-based physical activity programs.

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Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, p. 229. ISSN 0035-9173/22/020229-02

Thesis abstract

Contributions to blockchain-based security protocols

Yannan Li

Abstract of a thesis for a Doctorate of Philosophy submitted to The University of Wollongong, Wollongong, Australia

Blockchain is a prominent technology that revolutionises the way to do business and security, becoming a key advance worldwide. Dr Yannan Li's thesis focused on the design of blockchain-based secure applications. Specifically, she provided solutions in four essential scenarios: 1) regulation in blockchain-based cryptocurrencies, 2) blockchain-based decentralised e-voting, 3) contractual equivocation in blockchain; and 4) privacy protection in the stateless blockchain. Dr Li's thesis employs various advanced cryptographic techniques, including cryptographic commitments, zero-knowledge proofs, signatures of knowledge, verifiable encryption, cryptographic accumulators, and verifiable secret sharing, to design secure protocols and provide security proofs accordingly. All the protocols were implemented and the performance was provided to show the practicality of the proposal. Specifically, the four contributions of the thesis are listed as follows: First, Dr Li proposed Traceable Monero, to balance the anonymity and traceability in the system. As a result, the anonymity of an honest user is guaranteed, while a malicious user is subjective to be traced and identified for further penalty. The research outcomes have been published in IEEE Transaction on Dependable and Secure Computing (TDSC), a top journal in cybersecurity with CORE Rank A and IEEE Network, with impact factor 10.294. Second, Dr Li proposed a secure blockchain-based self-tallying voting system. No central party is required to tally the ballots and results can be calculated publicly while the privacy of all the ballots can be guaranteed. Besides, it satisfies fairness among all the users. This research outcome was published in IEEE TDSC, a top journal in cybersecurity with CORE Rank A. Third, Dr Li provided solutions for contractual equivocation in blockchain, which supports user-defined fine-grained policy-based equivocation. Dr Li presented a generic construction together with formal security proof. This paper was published in ACM ASIACCS, a top conference in cybersecurity with CORE Rank A. Fourth, Dr Li proposed mercurial subvector commitments and applied the new tool in stateless blockchain to capture privacy guarantee. A formal system and security models are provided, together with concrete construction. This research outcome was published in ACISP2021, a reputable conference in cybersecurity and this paper won the Best Paper Award. The research contributions of Yannan Li's PhD thesis is outstanding and the thesis is well-organised, as highlighted by the two external assessors whose expertise are in this research field. The thesis received the examiners' commendation for an outstanding dissertation and the Best Thesis Award in the Faculty of EIS, UOW.

In summary, Yannan's contributions to the research field as demonstrated in her PhD thesis have been outstanding, enabling further research in this area and will contribute to the blockchain industry. This thesis will attract further work in the area of blockchain, and its adoption in practice.

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Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, p. 231. ISSN 0035-9173/22/020231-02

Thesis abstract

Fluorescent sensor arrays to monitor heavy metals and therapeutic drugs in biological systems

Linda Mitchell

A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy at the University of Sydney

Rapid, sensitive and accessible detection of chemical analytes is a widespread challenge, particularly in remote communities that have limited access to technical facilities. Optical sensor arrays are a promising technique to address this challenge, and have demonstrated progress towards the detection of chemical analytes in the environment and in biological fluids. There are many chemical analytes with no suitable on-site detection system, and this thesis outlines the development of a number of new systems to address this gap.

A selection of coumarin sensors was first investigated to determine an optimal candidate for heavy metal ion discrimination. The systems took advantage of the cross-reactivity afforded by modifying the solvent. Of the four sensors investigated, a single thiocoumarin sensor was identified as the optimal candidate, and enabled the sensitive detection and discrimination of seven heavy metal ions.

The effectiveness of platinum chemotherapy is greatly limited by toxic side effects and varied patient tolerance. Therapeutic drug monitoring offers an opportunity to address these challenges, which many clinicians have attributed to ineffective dosing protocols. A six-sensor fluorescent array system was designed and synthesised to monitor various platinum species. The sensor array could distinguish platinum from other biologically relevant metal ions and separately able to discriminate platinum complexes with diverse coordination environments. Following this, the sensor array was utilised to monitor platinum levels in investigations using clinical plasma samples from patients undertaking platinum-based chemotherapy.

Polymers were recognised as promising materials for a potential drug detection sensor array. A strategy of functionalising amino acid mimics on a polymer backbone and a fluorophore on the polymer end-group was proposed. To this end, six polymers were synthesised and one polymer successfully modified with a coumarin fluorophore. The fluorescent polymer was utilised in investigations with a variety of analytes and solution conditions. Upon reaction with a library of antibiotics, the polymer displayed a unique fingerprint fluorescence response to each antibiotic. This result highlights the potential for this strategy to be utilised for future array-based detection of drug analytes.

The systems designed and utilised in this work have contributed significant progress towards the detection of chemical analytes in complex fluids. This thesis outlines the importance of new detection strategies for monitoring chemical analytes and how they can be translated to environmental

and clinical applications in remote areas of Australia.

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Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, p. 233. ISSN 0035-9173/22/020233-01

Thesis abstract

Coordination between chromosome translocation and peptidoglycan remodelling during spore development

Ahmed Mostafa Taha Mohamed

Abstract of a thesis for a Doctorate of Philosophy submitted to University of Technology Sydney, Sydney, Australia

Successful cell proliferation requires coordination between chromosome segregation and cell division. During bacterial development into spores, an asymmetric division results in two cells of different size and fate: a smaller forespore and a larger mother cell. Interestingly, the asymmetric septum forms over the forespore chromosome, trapping ~30% of the chromosome in the forespore, with the remaining 70% being translocated across the septum by the highly-conserved DNA translocase SpoIIIE. Asymmetric division also triggers cell-specific transcription that initiates remodeling of septal peptidoglycan. How these processes are coordinated has remained a mystery.

Using *Bacillus subtilis*, we demonstrate that peptidoglycan remodeling and chromosome segregation are coordinated at a highly-stabilized septal pore. This pore stability is maintained by multiple factors including SpoIIIE, a protein called SpoIIIM, peptidoglycan synthase PbpG and the highly-conserved SpoIIIAH-SpoIIQ interaction across the septal membrane. In the absence of these factors, peptidoglycan hydrolysis by DMP complex, and chromosome-induced turgor pressure on the septal peptidoglycan during chromosome translocation into the forespore, lead to septal pore expansion, loss of cytoplasmic and chromosomal compartmentalization, and a block to spore development. Overall, our work highlights how coordination between peptidoglycan remodeling and chromosome segregation is critical to ensure maintenance of genetic and cytoplasmic compartmentalization during development.

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Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, p. 234. ISSN 0035-9173/22/020234-02

Thesis abstract

Cooperative vehicle-to-everything communications for intelligent transportation system applications

Bach Long Nguyen

Abstract of a thesis for a Doctorate of Philosophy in Electrical Engineering submitted to The University of Newcastle, Callaghan, Australia

Of vehicle-to-everything (V2X) communications, vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) are the two technological innovations proposed to satisfy the stringent requirements of delay, service continuity and throughput in Intelligent Transportation Systems (ITS) applications, e.g. autonomous vehicle operation and stolen vehicle alert. However, in the stand-alone V2I networks, the sparse deployment and small coverage range of infrastructure units, e.g. road side units (RSUs), cause frequent service disruptions at requesting vehicles. Meanwhile, stand-alone V2V communications are intermittent and unreliable under high mobility and low vehicle density. Therefore, solutions that effectively combine V2I with V2V communications to meet the ITS application requirements, i.e. low service disruption and high achieved throughput, are called for. Additionally, the number of V2I and V2V links grows considerably when hundreds of vehicles request services at the same time. This leads to the question of how to allocate limited radio resources efficiently to a large number of links in ITS applications. In this study, we develop and evaluate a dynamic cooperative strategy and two scheduling schemes for V2I and V2V communications. The proposed approaches improve network connectivity in the scenarios where only one vehicle or many vehicles request the services simultaneously.

To maintain service continuity at a single requesting vehicle, we propose a dynamic forwarder selection to generate an adaptive multi-hop V2I and V2V path between the vehicle and the RSU that it has just passed by. Through an analytical model and extensive simulations using the practical settings of wireless channel and vehicular mobility, we show that: (i) The proposed scheme is a better choice than existing cooperation solutions in the sparse RSU scenarios; and (ii) A high vehicle density, more assistance willingness by the forwarders and larger buffer size at the requesting vehicle are shown to be beneficial for the proposed dynamic cooperation scheme.

To address the issue of insufficient radio resources, we design a frequency scheduling and power control scheme for when multiple vehicles download data via single-hop V2I and V2V communications in an RSU's coverage range. Mapping the V2I and V2V links to tuple-links, including multiple channel allocation, we formulate a mixed-integer nonlinear programming (MINLP) problem to maximize the number of concurrent tuple-links. To solve the problem, we apply the delayed column generation (DCG) method to propose an algorithm. Our main findings are: (i) This design minimizes

service disruptions compared to baseline scheduling approaches; and (ii) The proposed scheme not only improves average achieved throughput but also maintains throughput fairness among the requesting vehicles.

As the vehicles receive their requested data through multi-hop V2I and V2V paths in the area uncovered by any RSUs, we develop a frequency scheduling and power control scheme for multi-hop communications. Using the specific constraints of multi-hop transmission, we formulate a non-deterministic polynomial-time hard (NP-hard) problem to achieve the maximum number of active tuple-links within a sub-slot duration. Each tuple-link consists of multiple sub-slot and multiple channel allocations. After we design a DCG-based solution to the problem, our main findings are: (i) The proposed solution improves multi-hop network connectivity more than existing schemes when RSUs are deployed sparsely; and (ii) The efficiency of the proposed scheme can be further significantly enhanced by providing more available channels and equipping the requesting vehicles with a larger buffer size.

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Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, p. 236. ISSN 0035-9173/22/020236-02

Thesis abstract

Inheriting the disavowed: nuclear testing and its cultural symptoms in Australia

Annelise Roberts

Abstract of a thesis for a Doctorate of Philosophy submitted to the Australian National University

This dual creative/critical thesis examines the impact and legacy of the British nuclear testing program in Australia through the lens of a hypothesised cultural symptom called the "desultory:" a dull, avoidant half-heartedness, the signs of which, I argue, are apparent across various Australian cultural sites touched by nuclearism.

In the two-chapter scholarly dissertation, I use textual analysis to develop the concept of the desultory and suggest that its emergence can be traced to the conjunction of the existential anxieties of the nuclear era with the settler disavowal of colonial violence. The first body chapter considers the "black mist" — a phenomenon witnessed by many Aboriginal people in the wake of the first nuclear trial in 1953 — as an instance of the "nuclear uncanny." Reading a work of life writing by nuclear witness and Anangu woman Jessie Lennon, I find that the repressed cultural material that returns in the black mist phenomenon is connected to the unfinished, disavowed business of settler colonialism. Lennon's strong proclamation of Aboriginal survival through the work of life writing allows a clearer picture of the mechanisms of settler disavowal and obscuration to emerge, laying bare the program of the desultory. The second chapter suggests that the prevalence of Aboriginal-derived symbolism, imagery and language in representations of the nuclear project is further evidence of a cultural process of disavowal. In government surveyor Len Beadell's 1967 memoir and in the appropriative naming practices evident throughout the nuclear-testing operations, Aboriginality is both evoked and denied; ironically, it seems, the potential nuclear apocalypse is the only space in which the actual relationship between Indigenous and settler Australia can be faced. These two chapters provide a theoretical basis for the association between nuclear anxiety and the unacknowledged violence of Australia's colonisation, furnishing the conceptual ground for the broader project's theorisation of the desultory.

The creative component of the thesis, an epistolary novel called *Totem*, continues the work of theorising the desultory by other means. In *Totem*, a white nuclear veteran of the testing at Emu Field, South Australia, addresses a series of recollections to an unnamed descendant. Speaking from a *bardo* between life and death, the veteran is compelled to undertake the telling of his life story and the event at its core — his flight through the mushroom cloud of the Totem I nuclear test — by a sense that it is important for him to impart a legacy; however, he is continually hampered by his own forgetfulness, uncertainty, and fear. In the drama of the difficulty of telling his story a picture emerges of intergenerational silences, alienations and violences, and the odd cor-

respondence between the muteness of Canberra suburbia and the sublime emptiness of the testing site at Emu Field. Meanwhile, in a series of interludes, a woman works on a strange document — part memoir, part essay — against a backdrop of urban social dysfunction and decay. Her short treatises form a kind of return correspondence that culminates in a chronicle of an expedition to the heart of the continent in search of a foundation for her enquiry that has so far evaded her. Thematically, the novel dwells in the space where settler colonialism and nuclearism overlap; as suggested by the title — a word that refers both to an icon of Indigenous ancestry and to the first nuclear test on mainland Australia — Aboriginal dispossession is the "ground zero" of this narrative. In *Totem*, both the shock of the nuclear event and the confronting reality of colonial violence are diffused into desultory atmospheres of dulled complicity, in which clarity is consistently elusive.

(Dr Roberts was awarded the 2022 ANU JG Crawford Prize for Interdisciplinary research.)

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Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, p. 238. ISSN 0035-9173/22/020238-01

Thesis abstract

Topics in the theory of enriched accessible categories

Giacomo Tendas

A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy,
Macquarie University

The aim of this thesis is to further develop the theory of accessible categories in the enriched context. We study and compare the two notions of *accessible* and *conically accessible* V-categories, both arising as free cocompletions of small V-categories: the former under flat-weighted colimits and the latter under filtered colimits. These two notions are not the same in general, however we show that they coincide for many significant bases of enrichment such as **Cat** and **SSet**, and differ just by Cauchy completeness for many algebraic examples including **Ab**, R-**Mod** and **GAb**. We then provide new characterization theorems for these by considering some notions of *virtual orthogonality* and *virtual reflectivity* which generalize the usual reflectivity and orthogonality conditions for locally presentable categories. The word virtual refers to the fact that the reflectivity and orthogonality conditions are given in the free completion of the V-category involved under small limits, instead of the V-category itself. We then prove that the 2-category of accessible V-categories, accessible V-functors, and V-natural transformations has all flexible limits. In the final chapters we study, characterize, and provide duality theorems in the setting of accessible V-categories with limits of a specified class $\mathbf{\Psi}$; in this context, instead of the free completion under small limits, we consider "free completions" under a specific type of colimits $\mathfrak{C}$ for which, in particular, $\mathfrak{C}$-colimits commute in V with $\mathbf{\Psi}$-limits. This allows us to capture the theories of weakly locally presentable, locally multi-presentable, locally poly-presentable, and accessible categories as instances of the same general framework.

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Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, p. 239. ISSN 0035-9173/22/020239-02

Thesis abstract

Impact of community pharmacist interventions to manage medication adherence

Andrea Johanna Torres Robles

Abstract of a thesis for a Doctorate of Philosophy submitted to University of Technology Sydney, Australia

Background: As medication non-adherence continues to be a global public health problem, the development, evaluation and implementation of interventions to address this prevalent problem represent a key priority. Community pharmacists' role is evolving from the dispensing of medications to the provision of professional services aiming at improving patient outcomes. Pharmacists have, therefore, the potential to deliver interventions to manage medication adherence. Nonetheless, there is still a lack of evidence on the effect of community pharmacist-led interventions on medication adherence and clinical outcomes.

Objectives: To explore and evaluate the impact of medication adherence interventions undertaken by community pharmacists across different chronic diseases. This research aims to provide evidence on the efficacy and effectiveness of community pharmacist-led interventions in Australia and Spain on medication adherence to interventions and disease-specific outcomes.

Methods: Multiple methods were applied in this research. Chapter 2 presents a systematic review and network meta-analysis, following the PRISMA guidelines, comparing long-term interventions on the impact on medication adherence across different chronic diseases. Chapter 3 describes a retrospective observational study evaluating the impact of a real-life practice intervention in Australia provided by community pharmacists to patients with chronic medications (rosuvastatin, desvenlafaxine, irbesartan). Chapter 4 presents a cRCT to evaluate the impact of a medication adherence management service in a community pharmacy setting in Spain. Chapter 5 describes a sub-analysis of the cRCT including patients with asthma and COPD being prescribed inhaled medications. A multilevel regression model was used to measure the impact of the medication adherence management service on medication adherence and disease-specific clinical outcomes (Chapter 4) and inhaler technique (Chapter 5). Chapter 6 presents an effectiveness-implementation hybrid design evaluating the clinical impact of the medication adherence management service when translated to routine practice during an implementation study. For this analysis, patients were classified in three groups: A) those allocated to the intervention group during the cRCT and continue during implementation, B) those allocated to the control group during the CRCT and continue during implementation, and C) new patients in the implementation study.

Results: Chapter 3 presents the impact of a real-life community pharmacist-led intervention in Australia. De-identified data of 2,530,562 patients and 3,328 Australian

community pharmacies from 2014 to 2017 were contained in the database. A total of 1,805 pharmacies and 20,335 patients who met the inclusion criteria were included in the analysis, with an average age of 67 (SD: 11.76). Three months after the intervention was provided, there was an increase from 50.2% (SD: 30.1) to 66.9% (SD: 29.9) for rosuvastatin, from 50.8% (SD: 30.3) to 68% (SD: 29.3) for irbesartan and from 47.3% (SD: 28.4) to 66.3% (SD: 27.3) for desvenlafaxine, in adherence rates. Rates decreased over 12 months to 62.1% (SD: 32.0) (rosuvastatin), 62.4% (SD: 32.5) (irbesartan) and 58.1% (SD: 31.1) (desvenlafaxine).

The results of the cRCT are highlighted in Chapter 4. Patients (n = 1,186) were recruited from 98 pharmacies and 87.5% (n = 1,038) completed the six-month study. Compared to control patients, patients receiving the intervention had an Odds Ratio (OR) of 5.12 of being adherent at the end of the study. ORs for hypertension control, asthma control and COPD low clinical impact were 1.22 (95% CI: 0.78–1.91), 1.88 (95% CI: 1.05–3.36) and 2.01 (95% CI: 1.07–3.75), respectively, favouring the intervention group. For patients using inhaled medications (i.e. sub-analysis of patients suffering from asthma or COPD in the cRCT), the odds of improvement of patients with correct inhaler technique were 4.57 favouring the intervention group. The impact of the medication adherence management service resulted on an improvement on clinical outcomes (e.g. medication adherence and disease-specific outcomes) for all patients during the implementation study (i.e. routine-practice), with greater improvements observed in those patients who have not been exposed to the intervention before (groups B and C).

Conclusion: Community pharmacist-led interventions led to an improvement in medication adherence and disease-specific clinical outcomes. A real-life intervention in Australia resulted in the improvement of adherence after providing the intervention with an eventual decline on adherence rates post-intervention, highlighting the importance of continuous follow-up. To improve the effectiveness of this intervention, factors such as follow-up, fidelity measures and the addition of other components to the intervention should be considered. These factors were considered when developing a medication adherence management service in Spain. This intervention resulted in the improvement of medication adherence and disease-specific outcomes under the cRCT (controlled environment) and the implementation study (real practice). The intervention also improved inhaler technique on patients suffering from asthma and COPD and contained multiple components (e.g. educational, attitudinal, technical), which have been found effective at improving medication adherence. The essential role that community pharmacists have in the management of medication adherence should be considered in the development of future interventions.

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Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, p. 241. ISSN 0035-9173/22/020241-02

Thesis abstract

Mapping the graphic lexicon of *Emigre* magazine: a visualisation framework for the study of visual communication design artefacts and collections

Erin Jade Turner

Abstract of a thesis for a Doctorate of Philosophy submitted to the University of Technology Sydney, Sydney, Australia

This thesis explores the potential of *visualisation* as a means of inquiry. The primary aim of the research is the development of a visualisation *framework*, offering new possibilities for analytical tools to parse visual communication design artefacts and collections in order to identify, describe and elucidate their graphic language features. Given expanding access to digitised archives of graphic design, this research is well positioned to contribute to the methods design researchers use to investigate these collections and support formal analyses of the material they contain. In pursuit of this aim, the 20th-century typography and graphic design publication *Emigre* magazine (1984–2005), is used as a prototypal study. Contributing significantly to design history and practice, *Emigre* offers a rich and heterogeneous collection of material for investigation. Although the visualisation framework proposed in this thesis is applied to *Emigre*, it is applicable to visual communication design material more broadly. These visualisations provide new ways of seeing the *Emigre* collection; identifying and elucidating graphic language features enables more informed, nuanced statements to be made about the complex character of the material.

This framework, offering a suite of three *visual strategies* (*Emplacement*, *Amalgamation*, *Disassembly*) and nine *visualisation approaches*, emerges from an approach to data practice I have defined as an *expanded visualisation practice* (*EVP*). As a means of visual inquiry, an *EVP* offers an alternative or more expansive domain of practice than conventional visualisation. Conventional visualisations — reductive, quantitative studies of phenomena, such as graphs and charts — are limited in their capacity to respond to the graphic complexity and nuances of visual communication design artefacts and collections. A visualisation framework based on an *EVP* is proposed as a means of facilitating multidimensional understandings of this material, enabling researchers to *parse* graphic artefacts and collections, while maintaining the richness of the visual material, its context and complexity.

This thesis is situated within the model of *Research through Design*, which recognises the distinct contribution of design practice to scholarly inquiry and the production of knowledge. The knowledge produced through this approach to inquiry emerges from both the *practice* of visualisation (a process of *thinking-through-making*) and the *analysis* of the visual representations generated through this process. As research artefacts, the visualisations produced for this thesis evidence the potentiality of the

proposed framework and serve as an adaptable model for future study. These research artefacts provide new ways of seeing the *Emigre* collection; through an analysis of the visualisations, aspects of *Emigre*'s graphic lexicon are explicated. The prevailing narrative on *Emigre* and the narrow, idealised representation of its graphic expression are both extended.

The study of *Emigre* becomes a prototype investigation, formalising alternative means of analysing visual communication design material and demonstrating how visualisation can support the identification and elucidation of a particular graphic lexicon.

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Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, p. 243. ISSN 0035-9173/22/020243-01

Thesis abstract

Advancing knowledge on the antecedents and outcomes of team silence

Nate Zettna

A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy at the University of Sydney

In this thesis, I investigate the phenomenon of team silence — when team members collectively withhold their thoughts, opinions and suggestions about important work-related matters. Although scholars have theorized about team silence as a shared behaviour among team members and how as a shared property of the team it can vary between teams, few empirical studies have examined the antecedents and outcomes of team silence. As a result, there is a dearth of knowledge on the precise nature of team silence as a collective phenomenon, what impacts it, and how it impacts team outcomes. In this thesis, I conducted three empirical studies which together aim to advance knowledge on the contextual factors (e.g., leadership) that shape the shared behaviours of silence within teams; the processes by which team silence leads to detrimental team outcomes; and how certain changes in the work context may impact changes in team silence. Specifically, the first paper explores the nature of team silence in student teams in terms of the extent to which silence is a shared behaviour among team members, its distinction from related constructs (e.g., individual silence, voice), and its relationship with team satisfaction and performance outcomes. The second paper examines in field teams the antecedents and outcomes of team silence in a large commercial bank using a multi-wave, multi-source team study. In this second paper, I investigate how leaders who value the input of their teams can influence team silence and how these effects flow on to impact objective team performance outcomes. The last paper uses a quasi-experimental field study to investigate how team leader succession (i.e., a change in team leadership) influences team silence towards team leaders over time. This thesis advances much needed theoretical and practical knowledge about how team silence can undermine team effectiveness by preventing the surfacing of important problems within teams and the important role of leadership in creating team environments that can prevent and reduce team silence. Without a better understanding of silence within teams, organizations risk the loss of vital information that is crucial for teams to succeed. (Dr Zettina was a winner of the John C Harsanyi Graduate Medal.)

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Journal & Proceedings of the Royal Society of New South Wales, vol. 155, part 2, 2022, pp. 244–258. ISSN 0035-9173/22/020244-15

Royal Society of New South Wales 2022

Awards Winners 2022

The Awards for 2022 were announced at the 1309th Ordinary General Meeting of the Society, held on Wednesday, 7 December 2022. These included the Cook Medal, which is the Society's highest honour, and awards for research and scholarly excellence.

James Cook Medal

Emeritus Professor John Church AO FAA FTSE FAMS FAGU

Seven Awards for Research Excellence

Clarke Medal and Lecture (Geology)

Professor Andrew (Andy) Baker FAGU

Edgeworth David Medal

Dr Tim Doherty

History and Philosophy of Science Medal

Emeritus Professor Stephen Gaukroger FRSN FAHA FRHistS FRSA

Burfitt Prize

Distinguished Professor Susan Scott FAA FEurASc

Liversidge Memorial Lecture

Professor Timothy Schmidt FRSN FRACI CChem

Warren Prize

Professor Anita Wing Yi Ho-Baillie FRSN FAIP

Jak Kelly Award

Mr Shankar Dutt

Three Royal Society of NSW Scholarships

Ms Clara Liu Chung Ming, Mr Thomas Mesaglio, and Ms Anyang (Anya) Zhao

James Cook Medal

Emeritus Professor John Alexander Church AO FAA FTS FAMS FAGU

The James Cook Medal is awarded periodically by the Royal Society of New South Wales for outstanding contributions to science and human welfare in and for the Southern Hemisphere. **John Church**, an Emeritus Professor in the Climate Change Research Centre, UNSW Sydney is the world's pre-eminent authority on the rate of 20th century sea-level rise, with his work on quantifying historical changes having been pivotal in revolutionising our modern view of sea level rise, including the first detection of the acceleration in the rate of rise. His ground-breaking papers, published with both national and international colleagues, explain a long-standing conundrum about the causes for the observed 20th century sea-level rise. He has provided substantial improvements in estimates of ocean heat uptake, resolving discrepancies between observations and models as well as the causes. In addition, he has been an international leader in sea level assessments and projections and his work has established that anthropogenic climate forcing is responsible for the majority of observed sea level rise since 1970.

Seven Awards for Research Excellence

Clarke Medal and Lecture (Geology)

Professor Andrew (Andy) Baker FAGU

The Clarke Medal is awarded each year for distinguished research in the natural sciences, conducted in Australia and its territories, in the fields of botany, zoology, and geology (considered in rotation). For 2022, the medal has been awarded in geology. **Professor Andy Baker**, of the School of Biological, Earth & Environmental Sciences at UNSW Sydney, is an international authority in cave science, hydrology and geochemistry, especially as it pertains to our understanding of karst — complex underground systems formed from dissolution of soluble rocks, characterised by sinkholes, caves and speleothems (e.g., stalagmites). Having led over AU$10M in external projects in NSW since 2010, he has also published more than 260 internationally refereed papers, including highly-cited publications in *Nature*, *Nature Communications*, and *Science*.

Edgeworth David Medal

Dr Tim S. Doherty

The Edgeworth David Medal is awarded annually for distinguished research by a young scientist under the age of 35 years for work undertaken mainly in Australia or contributing to the advancement of Australian science. **Dr Tim Doherty**, an ARC DECRA Fellow in the School of Life and Environmental Sciences at the University of Sydney, has made extraordinary contributions in the fields of predator-prey dynamics, movement ecology and fire ecology, emerging as a pre-eminent scientist of his generation in developing these fields and in exploring how each is influenced by human modification of the environment. Dr Doherty's transformative insights have been achieved by combining field experiments with novel theoretical frameworks and global syntheses. Key contributions include revealing

that invasive predators have contributed to more than 50% of bird, mammal, and reptile extinctions globally, and conducting vital applied field research on fire and invasive species that informs conservation policy and management.

History and Philosophy of Science Medal

Emeritus Professor Stephen Gaukroger FRSN FAHA FRHistS FRSA

The Society's History and Philosophy of Science Medal is awarded annually to recognise outstanding achievements in the History and Philosophy of Science, especially the study of ideas, institutions, and individuals of significance to the practice of the natural sciences in Australia. **Emeritus Professor Stephen Gaukroger** is one of the world's leading historians of science and philosophy. Educated at the University of London and the University of Cambridge, he has held positions at Cambridge, Melbourne, and Sydney, as well as visiting professorships at Oxford, London, Aberdeen, and the *École normale supérieure — Paris Sciences et Lettres*. Now Emeritus Professor of History of Philosophy and History of Science at the University of Sydney, he is the author of sixteen books, including an internationally renowned intellectual biography of Descartes (1995). His work has been translated in Arabic, Chinese, French, German, Italian, Portuguese, and Russian. His major work is the 4-volume study of science and the shaping of modernity: *The Emergence of a Scientific Culture, 1210–1685* (2006); *The Collapse of Mechanism and the Rise of Sensibility: 1680–1760* (2010); *The Natural and the Human, 1739–1841* (2016); *Civilization and the Culture of Science, 1795–1935* (2020).

Burfitt Prize

Distinguished Professor Susan M. Scott FAA FEurASc

The Walter Burfitt Prize, established as a result of a generous gift to the Society by Dr W.F. Burfitt BA MB ChM BSc, is awarded at intervals of three years for research in pure or applied science. The winner must be resident in Australia or New Zealand, and whose papers and other contributions published during the past six years are deemed of the highest scientific merit. **Distinguished Professor Susan Scott**, from the Australian National University College of Science, is an internationally recognised mathematical physicist who has made fundamental advances in our understanding of the fabric of space-time in general relativity, and in gravitational wave science. She has pioneered breakthrough results probing the existence and nature of space-time singularities, the global structure of space-time, and possible initial and final endstates for cosmological models representing our Universe. Professor Scott has also been a pioneer in the analysis of astrophysical signatures in gravitational wave experiments, including the searches for gravitational waves from asymmetric neutron stars and from inspiralling binary systems of black holes and neutron stars. She has played an important role in the development and promotion of gravitational research worldwide, and a leading role in Australia's participation in the first direct detection of gravitational waves in 2015.

Liversidge Lectureship

Professor Timothy W. Schmidt FRSN FRACI CChem

The Liversidge Lecture, established under the terms of a bequest to the Society by Professor Archibald Liversidge MA LLD FRS, who was Professor of Chemistry in the University of Sydney from 1874 to 1907 and was one of the Council members who sponsored the Society's Act of Incorporation in 1881, is awarded at intervals of two years for the purpose of encouragement of research in Chemistry. **Professor Timothy Schmidt**, of the School of Chemistry at UNSW Sydney, is internationally recognised as a molecular spectroscopist working on diverse problems from astrophysics to renewable energy. In the gas phase, he has recorded spectra of many hydrocarbon radicals for the first time and discovered new electronic excitations of the dicarbon molecule. In the condensed phase, his work concentrates on triplet-triplet annihilation and singlet fission for solar energy applications. His work has been recognised by a number of prizes including the Broida Prize (International Symposium on Free Radicals 2015), the Coblentz Award (2010), the RACI Physical Chemistry Lectureship and the RACI Physical Chemistry Medal (2021).

Warren Prize

Professor Anita Wing Yi Ho-Baillie FRSN FAIP

The Warren Prize consists of a medal and lectureship in recognition of research by engineers and technologists in their early to mid-career. Early-career researchers will have established a publication record in top-tier journals and wish to reach a broader audience, while mid-career researchers will have completed a larger body of work relevant to society. **Professor Anita Ho-Baillie** is a pioneer in the development of next-generation solar cells that are key to transitioning to a carbon-free-economy. Focussing on multi-junction solar cells, the aim of her research is to increase their power conversion efficiency towards 40% and 50% when the efficiencies of commercially available silicon solar cells are around 25%. In addition, her recent breakthroughs in improving the durability of perovskite solar cells are critical steps towards commercial viability. Despite the early stage of her career, her outstanding contributions to the important field of energy research are recognised around the world. Four times a Clarivate Analytics Highly Cited Researcher, in 2021 she was named Top Australian Researcher in Sustainable Energy by *The Australian* and by leading journal *ACS Energy Letters*, one of 30 leaders in advancing perovskite solar cells and one of 40 Women Scientists at the Forefront of Energy Research in the World.

Jak Kelly Award

Mr Shankar Dutt

The Jak Kelly Award was created in honour of Professor Jak Kelly (1928–2012), who was Head of Physics at the University of NSW from 1985 to 1989, was made an Honorary Professor of the University of Sydney in 2004, and was President of the Royal Society of NSW in 2005 and 2006. Its purpose is to encourage excellence in postgraduate research in physics. The award is supported by the Royal Society of NSW and the Australian Institute of Physics, NSW branch. The winner is selected from a shortlist of candidates who made presentations

at the most recent Australian Institute of Physics (NSW Branch) postgraduate awards meeting. **Shankar Dutt** is a PhD Candidate in the Research School of Physics at the Australian National University. He investigates a nanopore-based sensing platform for the detection of different biomolecules in complex solutions including DNA, proteins and antibodies. This allows tailoring of the biomolecules' translocation kinetics and, combined with artificial intelligence, aims at early diagnosis of neurodegenerative disorders such as Alzheimer's Disease and Multiple Sclerosis.

Three Royal Society of New South Wales Scholarships

The Royal Society Scholarships are awarded annually in order to acknowledge outstanding achievements by young researchers in any field of science. Applicants must be enrolled as research students in a university in either NSW or the ACT on 1 January in their year of nomination.

For 2022, three RSNSW Scholarships have been awarded:

- Miss **Clara Liu Chung Ming** — PhD Candidate, School of Biomedical Engineering, University of Technology Sydney
- Mr **Thomas Mesaglio** — PhD Candidate, School of Biological, Earth, and Environmental Sciences, UNSW Sydney
- Ms **Anyang (Anya) Zhao** — PhD Candidate, John Curtin School of Medical Research, Australian National University

Miss Clara Liu Chung Ming is a PhD candidate in the School of Biomedical Engineering at the University of Technology Sydney under the supervision of Dr Carmine Gentile. Her research focusses on the bioengineering of advanced 3D *in vitro* models of the human heart pathophysiology, including "the-heart attack-in-a-Petri-dish" and heart failure using patient derived-stem cells. In particular, Clara has demonstrated that acetylcholine (a natural compound produced by our body) plays a protective role against myocardial infarction (heart attack) and drug-induced heart failure using her cells. Clara's multidisciplinary project is carried in collaboration with the University of Sydney/Charles Perkins Centre/Sydney Heart Bank, Royal Prince Alfred Hospital and Baker Heart and Diabetes Institute/Monash University. Clara's research has focussed also on the effects of SARS-CoV-2 on human heart pathophysiology, as well as the bioengineering of pre-eclampsia-induced heart failure using patient-derived stem cells. Her research has received several awards, including Australian Government Research Training Program Stipend (2021), FEIT HDR Women in Engineering and IT awards (2021), ASBTE Rapid Fire Presentation Award (2022) and NSW Education Waratah Scholarship (2022).

Mr Thomas Mesaglio works on quantifying our knowledge of Australian plant biodiversity, developing identification tools, survey and species description protocols and general data frameworks for improving this knowledge. Although much of his research focuses on analyses of 'citizen science' data, he has published scientific papers in disciplines including marine forensics, bushfire recovery and invertebrate ecology and taxonomy. As part of the Environment Recovery Project team, he received the Department of Industry, Science and Resources' 2022 Eureka Prize for Innovation in Citizen Science. He has published two

books: a guide to scientific etymology and a seashell field guide and is a curator and forum moderator on the citizen science platform iNaturalist, with 39,000 observations and 227,000 identifications made for other users.

Ms Anyang Zhao's research is focused on the clinically important foodborne pathogen called Listeria, which causes 20–30% of death in humans. She has identified that Listeria infection triggers inflammation and cell death, which are biological processes crucial for overcoming Listeria infection. Excessive inflammation caused by the immune system while fighting off Listeria infection can lead to sepsis and death. Ms Zhao's research aims to inhibit such excessive inflammation and could lead to the development of therapies against sepsis. During her first year of PhD study, Anyang published a preview article in *Cell Host & Microbe* (2022) as co-first author, and further co-authored two primary research articles in *Science Immunology* (2022) and *Nature Communications*. Her research achievements have been recognised by multiple prizes, scholarships and grants.

Events in 2022

Meetings held by the Society in four places: Sydney; Newcastle by the Hunter Branch; Mittagong by the Southern Highlands Branch; and western NSW by the Western NSW Branch.

1300th OGM and Open Lecture

"Where next for higher education after COVID-19?" *Professor Mark Scott* AO FRSN Vice-Chancellor and Principal, The University of Sydney; Date: Wednesday, 2 February 2022; Venue: Zoom webinar.

Annual Meeting of the Four Societies 2022

"Engineering and related Challenges in Decarbonising the Electricity System" *Professor Stephen Wilson*, University of Queensland. A joint meeting of the Australian Institute of Energy, the Australian Nuclear Association, the Sydney Division of Engineers Australia, and the Royal Society of NSW — this year organised by the Australian Nuclear Association. Date: Wednesday, 16 February 2022; Venue: The UTS Aerial Function Centre (Building 10, Level 7, 235 Jones Street, Ultimo) and via a Zoom webinar.

Southern Highlands Branch Meeting 2022-1

"Uranium: Australia's secure energy and climate solution" *Mr Robert Parker*, Former President, Australian Nuclear Association; Date: Thursday, 17 February 2022; Venue: RSL Mittagong, Carrington Room.

1301st OGM and Open Lecture

Royal Society of NSW 2021 Student Award Presentations: *Zain Mehdi*, ANU, *Sajad Abolpour Moshizi*, Macquarie University, *Harry Marquis*, University of Sydney, *Kevin Chau*, Macquarie University; Date: Wednesday, 2 March 2022; Venue: Zoom webinar.

RSNSW Bicentennial Garden Party, Government House, Sydney

On 12 March, Her Excellency, the Honourable Margaret Beazley AC QC, Governor of New South Wales, addressed the gathering and congratulated the Society on its 200th birthday.

Western NSW Branch Meeting 2022-1

"Public Trust and Science in Times of Coronavirus" *Robert Clancy* AM FRSN, *Michelle Grattan* AO FASSA and *Jane Quinn*, facilitated by Mark Evans; Date: Tuesday, 15 March 2022; Venue: Council Room 104, The Grange, Building 1205, Charles Sturt University (Bathurst) and Zoom live streaming.

Southern Highlands Branch Meeting 2022-2

"Transgenerational Epigenetics" *Dr Alyson Ashe*, Senior Lecturer, School of Life and Environmental Science, University of Sydney; Date: Thursday, 17 March 2022; Venue: RSL Mittagong, Carrington Room.

RSNSW Clarke Lecture 2020

"From bulldozers, pests, and pathogens to climate change and urban futures: the tough life of plants" *Professor Michelle Leishman*, Distinguished Professor of Biology, Director, Centre for Smart Green Cities, Macquarie University. Date: Thursday, 17 March 2022; Venue: Live Streaming only.

Frontiers of Science Forum 2022

"Exploring major discoveries and theories in physics, mathematics, biology, and chemistry" *The Hon. Alister Henskins* SC MP, *Prof Johannes Le Coutre* FRSN, UNSW Sydney, *Prof Benjamin Eggleton* FRSN FAA FTSE, University of Sydney, *Prof Chris Tisdell* FRSN, UNSW Sydney, *Prof. Martina Stenzel* FRSN FAA, UNSW Sydney. A joint meeting of the Australian Institute of Physics (AIP), the Teachers' Guild of NSW (TGNSW), the Royal Australian Chemical Institute (RACI), and the Royal Society of NSW; Date: Friday, 25 March 2022; Venue: Concord Golf Club, 190 Majors Bay Road, Concord.

The 2022 Annual General Meeting *and* The 1302nd Ordinary General Meeting

"New frontiers in smart sensor technology for a healthier, safer and sustainable future" *Professor Benjamin Eggleton* FRSN FAA FTSE, Director, University of Sydney Nano Institute and Co-Director, NSW Smart Sensing Network; Date: Wednesday, 6 April 2022; Venue: Gallery Room, State Library of NSW.

ANA 2022 Conference: Progress in Nuclear

Australian Nuclear Association Conference. The 14th Australian Nuclear Association Conference on Nuclear Science, Technology, and Engineering. Theme: Progress in Nuclear — Progress in Nuclear Power around the World; Applications of Nuclear Techniques; Advanced Reactors and Small Modular Reactors (SMRs); The role of Nuclear in addressing Climate Change. Date: 8 April 2022; Venue: UTS Aerial Function Centre, Level 7.

Ideas@theHouse: April 2022

Presented by Her Excellency the Honourable Margaret Beazley AC QC, Governor of NSW: "Nothing" *Richard Tognetti*, the Artistic Director of the Australian Chamber Orchestra; Date: Wednesday, 20 April 2022; Venue: Government House Sydney.

Southern Highlands Branch Meeting 2022-3

"Space Race 2.0" *Dr Bradley Tucker*, Astrophysicist and Cosmologist, Australian National University; Date: Thursday, 21 April 2022; Venue: RSL Mittagong, Carrington Room.

Hunter Branch Annual General Meeting 2022 *and* Hunter Branch Meeting 2022-1

"COVID-19: past performance, present practice, and future prospects" *Nick Talley* AC Distinguished Laureate Professor, University of Newcastle and Hunter Institute of Medical Research; Date: Wednesday, 27 April 2022; Venue: Newcastle Club, 40 Newcomen Street, Newcastle.

RSNSW Liversidge Lecture 2020 *(delayed by COVID)*

"Drug Discovery Inspired by Natural Products " *Professor Richard J Payne* FRSN FRSC FRAC, Professor of Organic Chemistry and Chemical Biology, The University of Sydney; Date: Wednesday, 4 May 2022; Charles Perkins Centre Auditorium (D17), University of Sydney.

RSNSW Poggendorff Lecture 2020 *(delayed by COVID)*

"Are our weeds becoming new native species?" *Professor Angela Moles* of the UNSW School of Biological, Earth, and Environmental Sciences; Date: Wednesday, 11 May 2022; Venue: Royal Botanic Garden Sydney, Palm House.

Western NSW Branch Meeting 2022-2

"Making a living on the plains — Stone tools and archaeology of Aboriginal societies" *Dr Colin Pardoe* FRSN MAI ATSIS Biological Anthropologist and Archaeologist; Date: Wednesday, 18 May 2022; Venue: Wal Fife Lecture Theatre (Building 14, Room 212), Charles Sturt University (Wagga Wagga Campus) and live-streaming by Zoom.

Southern Highlands Branch Meeting 2022-4

"Longer life and fertility: the promise of ageing research" *Dr Lindsay Wu* NH & MRC Senior Research Fellow UNSW Sydney; Date: Thursday, 19 May 2022; Venue: RSL Mittagong, Carrington Room.

1303rd OGM and Open Lecture

"Federalism, borders, and National Cabinet — What has the pandemic taught us?" *Professor Anne Twomey* AO Professor of Constitutional Law, Sydney Law School, University of Sydney; Date: Wednesday, 1 June 2022; Venue: Gallery Room, State Library of NSW, Video presentation: YouTube video.

RSNSW Clarke Memorial Lecture 2021

"The changing tide of human populations: an infertility trap" *John Aitken* FRSE FRSN FAA FAHMS Distinguished Emeritus Laureate Professor School of Environmental and Life Sci-

ences, University of Newcastle; Date: Friday 10 June 2022; Venue: The University Conservatorium, Laman Street, Cooks Hill, Newcastle.

Southern Highlands Branch Meeting 2022-5

"From the RNA world to building an RNA ecosystem" *Professor Pall Thordarson*, Director, UNSW RNA Institute, UNSW Sydney; Date: Thursday, 16 June; Venue: RSL Mittagong, Carrington Room.

Joint AIP, RACI, RSNSW, and ANSTO Presentation

"Big Science of Gen IV Power Reactors" *Dr Mark Ho*, Reactor Heat Transfer Specialist, ANSTO, Vice-President, Australian Nuclear Association. A joint presentation by the Australian Institute of Physics (AIP), the Royal Australian Chemical Institute (RACI), the Royal Society of NSW (RSNSW), and the Australian Nuclear Science and Technology Organisation (ANSTO); Date: Tuesday, 21 June 2022; Venue: Hybrid — ANSTO Discovery Centre, Lucas Heights NSW and live streaming.

RSNSW 200th Anniversary Dinner

Date: Friday 24 June 2022; Venue and times: Chau Chak Wing Museum (pre-dinner drinks) 6–7 pm followed by dinner (7–10 pm) in the Great Hall, The University of Sydney.

RSNSW Exhibition: NEXUS

Jean Garling Room, Mitchell Building, State Library of NSW.

Pamela Griffith Exhibition — "Art and Nature"

Pamela Griffith FRSN, Sydney Artist and Printmaker; Date: 24 June–5 July 2022 — Opening Sunday, 26 June 2–4 pm (Speaker: *Dr Saul Griffith* FRSN); Venue: Broadhurst Gallery, Hazelhurst Arts Centre, 782 Kingsway, Gymea.

Display of Society-related objects in the Chau Chak Wing Museum, University of Sydney

On weekends 12.00 pm–4.00 pm from Saturday 1 July 2022, until Sunday 25 September 2022.

1304th OGM and Open Lecture

"This is going to be different: Learning to live with Chinese Power" *Professor Hugh White* AO FASSA Emeritus Professor of Strategic Studies, Australian National University; Date: Wednesday, 6 July 2022; Venue: Gallery Room, State Library of NSW.

Southern Highlands Branch Meeting 2022-6

"The Rise of Fragility and Poor Mental Health in our Youth: Where are we going wrong?" *Clare Rowe*, Educational and Developmental Psychologist, Rowe and Associates Child and Family Psychology; Date: Thursday, 21 July; Venue: RSL Mittagong, Alexander Room.

Hunter Branch Meeting 2022-3

"The Intersection between Science and Law" *Dr Xanthé Mallett*, Associate Professor of Criminology, University of Newcastle; Date: Thursday, 28 July 2022; Venue: Newcastle Club, 40 Newcomen Street, Newcastle.

1305th OGM and Open Lecture

"Marsupials: Their secrets are all in their genes!" *Professor Kathy Belov* AO FRSN FAA, Professor of Comparative Genomics and Pro-Vice-Chancellor (Global Engagement), University of Sydney, and *Dr Elizabeth Deane* FRSN, Education Consultant; Date: Wednesday, 3 August 2022; Venue: Zoom webinar.

Ideas@theHouse: August 2022

Presented by Her Excellency the Honourable Margaret Beazley AC QC, Governor of NSW: "Manufacturing at the Atomic Scale" *Scientia Professor Michelle Simmons* AO FRS DistFRSN FAA FTSE, UNSW Sydney, Director, ARC Centre of Excellence (CQC2T), Founder, Silicon Quantum Computing; Date: Thursday, 4 August 2022; Venue: Live-streamed from Government House Sydney.

2022 Ben Haneman Lecture

"Virus on the march? Military model and metaphor in the COVID-19 pandemic" *Professor Warwick Anderson* FRSN FAHA FASSA FAHMS, Professor of History, University of Sydney; Date: Thursday, 11 August 2022; Venue: Friends Room, Mitchell Building, State Library of NSW.

Southern Highlands Branch Meeting 2022-7

"The cycle of rainfall in Eastern NSW" *Professor Michael Asten*, retired Professor of Geophysics, and *Professor Ken McCracken* FAAS; Date: Thursday, 18 August 2022; Venue: RSL Mittagong, Carrington Room.

1306th OGM and Open Lecture

"Is Fairweather an Australian artist? And does it matter?" *Claire Roberts* FAHA, Associate Professor of Art History, University of Melbourne, in conversation with *Nicholas Jose*, Novelist and Emeritus Professor, University of Adelaide; Date: Wednesday, 7 September 2022; Venue: Zoom webinar.

Southern Highlands Branch Meeting 2022-8

"Scattering neutrons to explore the materials found on the dwarf planets of our solar system" *Dr Helen Maynard-Casely*, Senior Instrument Scientist, ANSTO; Date: Thursday, 15 September 2022; Venue: RSL Mittagong, Carrington Room.

In memory of Emeritus Professor Robin King FRSN

"Our respects to Emeritus Professor Robin King, FRSN FTSE HonFIEAust CPEng (Ret)"A hybrid memorial event organised by Engineers Australia; Date: Tuesday, 20 September 2022; Venue: Engineers Australia Sydney Office, Mezzanine Floor, 44 Market Street, Sydney or online webinar.

1307th OGM and Open Lecture

"The Global Economy and Australia's Outlook: Geoff Harcourt's contribution to the theory of productivity growth" Geoff Harcourt FRSN (1931–2021).[1] *Dr Don Russell*, Chair, Australian Super, *Ms Jane Drake-Brockman*, Visiting Fellow, University of Adelaide, and *Emeritus Professor Robert Marks* FRSN; Date: Wednesday, 5 October 2022; Venue: Gallery Room, Mitchell Building, State Library of NSW and YouTube video.

Southern Highlands Branch Meeting 2022-9

"Judging a Jest: Humour and Censorship" *Dr Jessica Milner Davis* FRSN, Honorary Research Associate, University of Sydney; Date: Thursday, 20 October 2022; Venue: RSL Mittagong, Carrington Room.

ATSE ACTIVATE Conference 2022

ACTIVATE: A tech-powered human-driven future; A STEM symposium presented by the Australian Academy of Technological Sciences & Engineering; Dates: 25–27 October 2022; Venue: the Sydney Masonic Centre Conference Centre, Sydney and live streaming.

RSNSW and Learned Academies Forum 2022

"Reshaping Australia: Communities In Action," supported by Her Excellency the Honourable Margaret Beazley AC KC, Governor of New South Wales and the Office of the NSW Chief Scientist and Engineer. Dates: Thursday 3 November 2022; Venue: YouTube live streaming from Government House Sydney.[2]

RSNSW Bicentennial Reception, Admiralty House, Sydney

On 3 November, His Excellency, General The Honourable David Hurley hosted a Reception for the Society; he spoke, the President responded, and Mrs Hurley had written a poem to celebrate the occasion.

Joint RSNSW-Law Society of NSW Public Lecture

"The US Supreme Court: A Rogue Court in a Fragile Democracy" *Linda Greenhouse*, Senior Research Scholar, Yale Law School and President, American Philosophical Society; Date: Monday, 14 November 2022; Venue: webinar.

2022 Linnean Society of NSW Natural History Field Symposium

"Natural History of the Northeastern Sydney Basin;" Dates: Wednesday/Thursday 16–17 November (oral presentations), Friday 18 November (field trip); Venue: Hornsby RSL Club, 4 High Street, Hornsby (oral presentations), Kuring-gai Chase National Park, West Head (field trip).

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[1] See his obit at P. Kriesler, T. Harcourt, and R. Marks. Geoffrey Harcourt AC FRSN (1931–2021), *Journal & Proceedings of the Royal Society of New South Wales* 155: 119–121.

[2] The proceedings of the Forum will be published in the June 2023 issue of the *Journal & Proceedings*.

Southern Highlands Branch Meeting 2022-10

"Green Steel" *Dr Samane Maroufi*, Centre for Sustainable Materials, Research and Technology, UNSW Sydney; Date: Thursday, 17 November 2022; Venue: RSL Mittagong, Carrington Room.

1308th OGM and 2021 Pollock Memorial Lecture

"Most of our universe is missing!: Adventures in the dark side of the cosmos" *Professor Geraint Lewis* FRSN FLSW, Professor of Astrophysics, Sydney Institute of Astronomy, University of Sydney; Date: Wednesday, 23 November 2022; Venue: Gallery Room, State Library of NSW.

RSNSW Poggendorff Lecture 2021

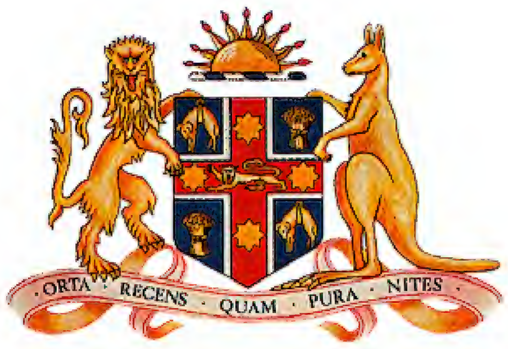
"A plant breeder's perspective on food security and climate change" *Professor Richard Trethowan*, Professor of Plant Breeding, Director, Plant Breeding Institute, Sydney Institute of Agriculture, University of Sydney; Date: Wednesday, 30 November 2022; Venue: Ground Floor Auditorium, Michael Spence Building, University of Sydney Camperdown Campus.

1309th OGM and Open Lecture

"Harnessing solar energy through catalysis to make chemicals and fuel" *Professor Rose Amal* AC FRSN FAA FTSE Scientia Professor of Engineering, School of Chemical Engineering, UNSW Sydney; Date: Wednesday, 7 December 2022; Venue: Gallery Room, State Library of NSW and video presentation.

Note on Gazetting

The Government Gazette of the State of New South Wales is managed by the New South Wales Parliamentary Counsel's Office and has published Government notices, regulations, forms and orders since 1832. It went on line in 2001 and since 2014 is only to be found at https://www.legislation.nsw.gov.au/#/gazettes.



Government Gazette

of the State of

New South Wales

Number 50–Other
Friday, 11 February 2022

On the initiative of RSNSW Fellow Robert Whittaker AM FRSN, the Society approached His Excellency the Governor to formally gazette fellows of the Society. All current fellows were included in the first gazetting in 2018, and subsequently at the beginning of each year fellows elected in the previous year will appear in the Gazette.

As the Gazette of Friday 11 February 2022 says:

> "Her Excellency, The Honourable Margaret Beazley AC QC, Governor of New South Wales, as Patron of The Royal Society of New South Wales and in furtherance of the aims of the Society in encouraging and rewarding the study and practice of Science, Art, Literature and Philosophy, is pleased to advise and acknowledge the election of the following as Fellows of the Society in 2021."

Fellows

Proven leaders and experts in their field, entitled to use the post nominal FRSN. Please note Professorial titles — including adjuncts, conjoint, and professors of practice — have been used where applicable. Details as to their field of expertise, their resident university (or universities) or institution may be ascertained from the Royal Society of New South Wales.

ADAMS, Professor David John Adams FRSN

BALLARD, Professor John William Oman Ballard FRSN

BOLTON, Professor Philip Stewart Bolton FRSN

BOWEN, Ms Carolyn Jan Bowen AM FRSN

BUCKINGHAM, Dr Jennifer Buckingham FRSN

BYARD, Professor Roger William Byard AO FRSN

CHEN, Professor Min Chen FRSN

COLEBORNE, Professor Catharine Siobhan Coleborne FRSN

COPPERSMITH, Professor Susan Nan Coppersmith FRSN

COSTER, Professor Adelle Coster FRSN

DANAIA, Associate Professor Lena Joel Danaia FRSN

DAWES, Professor Judith Margaret Dawes FRSN

DEVITT, Dr Simon John Devitt FRSN

EBACH, Dr Malte Christian Ebach FRSN

ECCLES, Mr Jeremy Robin Eccles FRSN

FORD, Professor Michele Therese Ford FRSN

FORSTER, Professor Lesley Susan Forster FRSN

GAL, Professor Ofer Gal FRSN

GALLIOTT, Dr Jai Galliott FRSN

GORE, Professor Jennifer Mary Gore FRSN

GRIGG, Professor Gordon Clifford Grigg FRSN

GURR, Professor Geoffrey Gurr FRSN

HERNOT, Mr Yves Pol Hernot KONM (France) FRSN

HO, Professor Simon HO FRSN

HOGG, Dr Carolyn Jane Hogg FRSN

HULBERT, Emeritus Professor Anthony John Hulbert FRSN

IVERS, Professor Rebecca Quentin Ivers FRSN

JACKSON PULVER, Professor Lisa Rae Jackson Pulver AM FRSN

JAGOSE, Professor Annamarie Ruston Jagose FRSN

KAPLAN, Emeritus Professor Gisela Kaplan FRSN

LEACH SCULLY, Dr Jackie Leach Scully FRSN

LITTLE, Professor Christopher Bond Little FRSN

LO, Professor Nathan Lo FRSN

LUCK, Associate Professor Morgan Joel Luck FRSN

MARINO, Professor Francesco Marino FRSN

MARTIN, Professor Jennifer Louise Martin FRSN

MCKAY, Ms Kim Coral McKay AO FRSN

MCLEOD, Professor Sharynne McLeod FRSN

MEERS, Ms Samantha Doreen Meers AO FRSN

MILLER, Professor Seumas Roderick Miller FRSN

MINASIAN, Professor Robert Minasian FRSN

MORRIS, Dr John Gruffydd Morris FRSN

MORRISON, Professor Mark Daniel Morrison FRSN

MOTION, Associate Professor Alice Elizabeth Motion FRSN

NAPPER, Emeritus Professor Donald Harold Napper AM FRSN

NELSON, Professor Janet Elizabeth Nelson FRSN

NETO, Professor Chiara Neto FRSN

OAKES, Professor Samantha Richelle Oakes FRSN

OPPERMANN, Dr Ian James Oppermann FRSN

PARDOE, Dr Colin Pardoe FRSN

POOLE-WARREN, Professor Laura Poole-Warren AM FRSN

POTTS, Professor Jennifer Robyn Potts FRSN

PRENZLER, Dr Paul David Prenzler FRSN

RENDINA, Professor Louis Michael Rendina FRSN

RINGER, Professor Simon Peter Ringer FRSN

ROGERS, Emeritus Professor Lesley Joy Rogers FRSN

ROSS, Professor Pauline Mary Ross FRSN

RYAN, Professor Michael John Ryan FRSN

RYAN, Mr Robert Francis Ryan FRSN

SCHOUTEN, Mr Peter Mark Schouten AM FRSN

SHARPLES, Professor Jason John Sharples FRSN

SORRELL, Professor Charles Christopher Sorrell FRSN

SPILSBURY, Ms Georgina Amanda Spilsbury FRSN

STAMPFL, Professor Catherine Margaret Stampfl FRSN

STEWART, Professor Mark Gerard Stewart FRSN

SULLIVAN, Professor Leigh Albert Sullivan FRSN

SUTER, Associate Professor Rebecca Suter FRSN

TOWN, Emeritus Professor Graham Edward Town FRSN

VARADY, Dr Margaret Louise Varady AO FRSN

WAKELIN, Dr Laurence Patrick George Wakelin FRSN

WALSH, Scientia Professor Toby Walsh FRSN

WANG, Associate Professor Qinlin Wang FRSN

WEBSTER, Emeritus Professor Ian William Webster AO FRSN

WONG, Mr Albert Yue Ling Wong FRSN

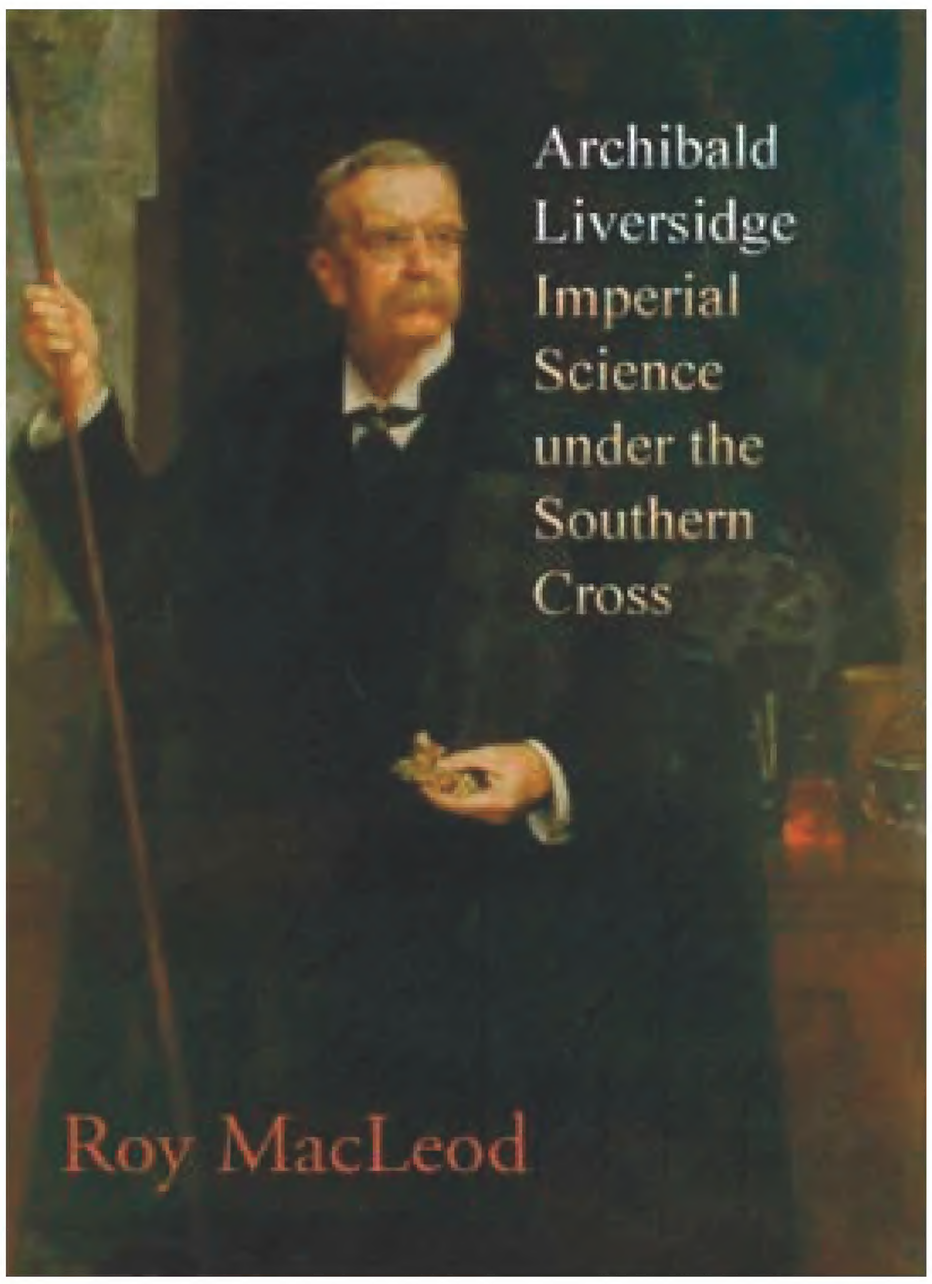
WONG, Dr Danny KY Wong FRSN

YI, Professor Xiaoke Yi FRSN

YONG, Professor Ken-Tye Yong FRSN

Archibald Liversidge:
Imperial Science under the Southern Cross

Roy MacLeod
Royal Society of New South Wales, in association with Sydney University Press
ISBN 9781-9208-9880-9



When Archibald Liversidge first arrived at the University of Sydney in 1872 as Reader in Geology and Assistant in the Laboratory, he had about ten students and two rooms in the main building. In 1874, he became Professor of Geology and Mineralogy and by 1879 he had persuaded the University Senate to open a Faculty of Science. He became its first Dean in 1882.

In 1880, he visited Europe as a trustee of the Australian Museum and his report helped to establish the Industrial, Technological and Sanitary Museum which formed the basis of the present Powerhouse Museum's collection. Liversidge also played a major role in establishing the *Australasian Association for the Advancement of Science* which held its first congress in 1888.

This book is essential reading for those interested in the development of science in colonial Australia, particularly the fields of crystallography, mineral chemistry, chemical geology and strategic minerals policy.

To order your copy, please complete the Liversidge Book Order Form available at:

https://royalsoc.org.au/images/pdf/McLeod_Liversidge_Order_Form_Rev.pdf

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The Royal Society of NSW,
(Liversidge Book),
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Crows Nest NSW 1585,
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The Royal Society of New South Wales

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If the file-size is too large to email it should be placed on a USB drive (or other digital media) and posted to:

The Honorary Secretary (Editorial),
The Royal Society of New South Wales,
PO Box 576,
Crows Nest, NSW 1585
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Information for Authors Inside Back Cover

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ISSN 0035-9173

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Published December 2022